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SCOTT'S FIRST BOOKS IN SCIENCE.

CHEMISTRY.

46.

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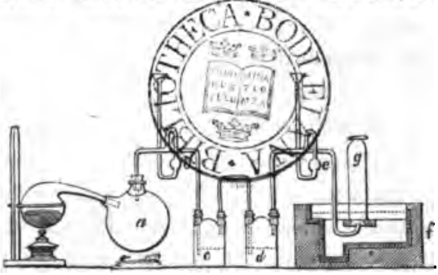
SCOTT'S FIRST BOOKS IN SCIENCE.

A TREATISE
ON
CHEMISTRY:
WITH
QUESTIONS ON EACH PAGE, AND A GLOSSARY OF TERMS.

BY
RICHARD D. HOBLYN, A.M., Oxon.
AUTHOR OF MANUELS OF CHEMISTRY, THE STEAM ENGINE, ETC.



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THE present Treatise forms an appropriate sequel to the preceding First Book on Heat, Light, and Electricity, and comprises a brief, yet comprehensive, sketch of our knowledge of Inorganic Chemistry. To the youthful philosopher, Chemistry presents the peculiar attraction of being essentially an *experimental* study, while the practical illustration of its facts are placed within the reach of all. "He who provides himself," says Dr. Reid, "with a few slips of glass, a few phials with acids and alkalies, and a small quantity of fifty or sixty of the more important chemical preparations—all of which, both apparatus and materials, he can procure for five or six shillings at the utmost—not only provides himself with a small museum to which he can continually refer, but can also perform, again and again, with a part of the materials, several thousand experiments. He can, moreover, renew them at his own convenience, whenever it may be desirable; he can study them leisurely at home with his text-book before him, and repeat those which may be more complicated, till he becomes familiar with them."

R. D. H.

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FIRST BOOK OF CHEMISTRY.

CHAP. I.

OF CHEMICAL ACTION.

1. The object of Chemistry is to examine into the composition of the numerous forms of matter which occur in the organic and the inorganic kingdoms of nature, and to investigate the laws by which the combination and the decomposition of their parts are effected. *Matter* is the general designation of all substances possessing *weight*, as distinguished from light, heat, and electricity, which, being destitute of appreciable weight, are commonly termed "imponderable agents." Although material, or ponderable, substances present a vast variety of forms, yet chemists have not been able to detect more than fifty-five bodies which may be termed *simple*, as containing only one kind of matter; of these, four only are found in organic nature. *Compound* bodies are those formed by combination of the simple or elementary bodies; thus, metallic iron is a simple body, but the rust of iron, being a combination of the metal with oxygen, is a compound body. Upon the same principle, earth, fire, air, and water, are not simple bodies, or *elements*, as they are sometimes erroneously called, but compound substances, each containing two or more simple bodies, held together by a particular force, termed chemical attraction or affinity.

2. The *physical* properties of matter, as inertia, divisibility, &c., belong to the study of Natural Philosophy, and must be carefully distinguished from its *chemical* properties. The attraction which determines chemical combination, is of a very different character from those forms of attraction, which, under the names of cohesion and gravitation, affect the materials of our globe and the nature of

---

1. What is the object of chemistry? What is meant by matter? How many simple bodies have been discovered? What are compound bodies?—2. Give some instances of mechanical mixtures, and state wherein they differ from chemical combinations. Illustrate the peculiarity of chemical attraction in the formation of cream of tartar from its elements.

all bodies existing upon it. 1. If water be mixed with water, or salt with salt, the effect is merely an increase of *quantity;* no change of *quality* is produced. 2. If a blue and a yellow powder be mixed together, a green powder is produced; but this is merely an effect impressed upon the eye by the intimate *mixture* of the yellow and blue light which is separately reflected from the minute particles of each; these particles may be separated mechanically, and the powders restored to their former appearance. 3. If two coloured liquids, having no chemical attraction for each other, be mixed together, a liquid of a different colour is produced, and the two ingredients cannot, it is true, be mechanically separated; yet, even in this case, the liquid is a mere *mixture,* and its properties are accordingly intermediate between those of the liquids mixed. In these three cases there is *no change of property,* nor is any new property superadded. 4. But when potash dissolved in water is mixed with tartaric acid also dissolved in water, a solid substance, cream of tartar, is thrown down in the vessel; this substance is neither potash nor tartaric acid, nor can either of these substances be again procured from it; the liquid also from which it subsided no longer presents the qualities of the ingredients which were mixed in it, but those of a *new* and entirely *different* substance. The potash and tartaric acid have, therefore, *united* with each other, to form a *chemical compound,* which, when carefully collected, is exactly of the same weight as the ingredients possessed before their union, but of entirely different qualities. The force by which this new substance is formed is called *chemical attraction* or *affinity*—a force of the highest importance in chemistry, inasmuch as the whole science includes little more than the knowledge of the laws and effects of chemical attraction and repulsion.

PHENOMENA OF AFFINITY.

3. Different bodies are affected by chemical affinity in different degrees. 1. Water combines readily with alcohol, feebly with ether, and scarcely at all with oil. 2. Sugar dissolves readily in water, sparingly in alcohol; while camphor dissolves freely in alcohol, and sparingly in water.

---

3. State some cases of chemical affinity, as exhibited between different bodies.

3. A rod of gold, plunged into a vessel of water, and then withdrawn, retains but little of the liquid on its surface, and this may be easily removed; but, on repeating the experiment with mercury, a coating of this metal adheres to the rod, and cannot be removed; the gold is rendered white, and, if the surface be scraped, the portions thus removed contain gold and mercury united by chemical attraction. 4. A piece of tin may be made to float on melted lead; but, as the tin melts, it becomes intimately united with the lead, and each particle of the compound, when solid, will be found to consist of both metals; in this case, the force of attraction counteracts that of gravitation. 5. The air inhaled in the act of respiration is different from that which is exhaled; on breathing through a tube into lime water, a *combination* takes place between the carbonic acid, an ingredient of the exhaled air, and the lime, and a white substance, chalk, is formed in the liquid.

4. *Single Elective Affinity.*—The simple combination of two substances, which have an affinity for each other, is of familiar occurrence, and is readily understood. But chemical combination is frequently attended by peculiar phenomena, of a more complex nature. There are three substances in general use, magnesia, lime, and nitric acid, commonly called aqua fortis. The nitric acid has an affinity for magnesia, and will combine with it; it has also an affinity for lime, and will also combine with it. On mixing these three substances together, in equal quantities, it might, therefore, be expected that they would all combine together. The result, however, is that *only one* of the affinities is obeyed: the nitric acid combines with the lime, leaving the magnesia uncombined and altogether unaffected. This case not only affords a further illustration of the principle laid down in the preceding paragraph—that different bodies are affected by affinity in different degrees—but it exemplifies a *preference*, or choice, which bodies evince, in combining with one substance, and rejecting others. This phenomenon was termed by Bergmann *single elective affinity.*

5. Upon the same principle the formation of a compound

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4. What is single elective affinity? Illustrate its operation on mixing together lime, magnesia, and nitric acid.—5. Describe a case in which its operation is attended by decomposition. State the order of decomposition which takes place when sulphuric acid is brought into contact with the several substances quoted in the table.

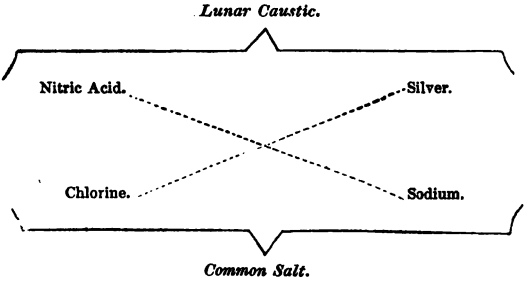
is frequently attended by the *destruction* of a previously existing compound, as when some third body acts upon a compound, for one element of which it has a greater affinity than for the other. This may be illustrated by the above-mentioned bodies. If the nitric acid be already combined with the magnesia, and the lime be added to the compound, the result will be that the magnesia will be separated from the lime, which will take its place, and combine with the acid; the magnesia, which was formerly dissolved in the acid, and invisible, will re-appear and be perfectly separate. The former compound is decomposed; and this process is termed *decomposition.* 2. If camphor be dissolved in alcohol, and the solution be poured into water, the alcohol quits the camphor, and combines with the water; the camphor is thus set free, and appears as a separate body. 3. If sulphuric acid be added to a combination of nitric acid and baryta, it separates the baryta, leaving the nitric acid free. In each of the three last cases, combination and decomposition take place. The order in which these decompositions occur, may be expressed in tables, as in the following, by Geoffroy:—

Sulphuric Acid.

1. Baryta
2. Strontia
3. Potassa
4. Soda
5. Lime
6. Ammonia
7. Magnesia.

According to this table, sulphuric acid has an affinity for all the substances placed beneath it, and will combine separately with each; and each of the compounds, thus formed, may be decomposed by adding to it any of the substances placed above it in the table. Thus, ammonia will separate magnesia from sulphuric acid, lime will separate ammonia, and soda lime; but magnesia will not separate ammonia, nor ammonia lime, nor will any of them separate baryta from sulphuric acid. This *order of decomposition* does not, however, represent the comparative *forces of affinity;* other causes are in operation which modify the force of affinity to such a degree, that the amount of the effect produced by this power cannot be determined. The table, therefore, represents the order of decomposition, not that of affinity.

6. *Double Elective Affinity.*—Affinity is frequently the cause of still more complicated changes. In those above described, three substances only were present, and *two* affinities in operation. But when two compounds are mixed together, both of them may be decomposed, and *four* affinities exhibited. 1. *Lunar caustic* consists of nitric acid and silver, *common salt* consists of chlorine and sodium. On mixing a solution of these compounds together, the nitric acid leaves the silver, and combines with the sodium, forming a salt which remains in solution; on the other hand, the chlorine quits the sodium, and combines with the silver, forming a curdy substance, which falls to the bottom of the containing vessel. These *changes* may be represented by the following *diagram*:—



In this case, the nitric acid and the chlorine have each an affinity for the silver and the sodium; but the nitric acid *prefers* combining with the sodium, to remaining in combination with the silver; and a corresponding *preference* is exhibited by the chlorine. The previous combinations are, therefore, destroyed, and two new ones produced; the results are the formation of two new compounds, viz. nitrate of soda, and chloride of silver. This process is termed *double elective affinity;* and it is accompanied by a *double decomposition.*

---

6. What is double elective affinity? Explain the decompositions and affinities which take place when lunar caustic is mixed with common salt.

CHANGES INDUCED BY CHEMICAL ACTION.

7. *Change of Properties.*—Substances which have entered into combination generally exhibit an entire *change of properties:* the elementary ingredients have lost their former properties, and have acquired new ones: —1. *Water*, a liquid, consists of two gases, hydrogen and oxygen, neither of which has ever been compressed into a liquid; hydrogen is one of the most inflammable bodies in nature, but water cannot be inflamed; oxygen supports combustion with great brilliancy, but water extinguishes combustion. 2. *Common Salt*, which is not only harmless, but absolutely necessary for man, consists of two formidable ingredients, viz. the metal sodium, and the gas chlorine; either of which taken into the stomach is fatal to life. When presented to each other, they burst into flame, and instantly lose their dangerous properties. 3. *Glauber's Salt*, a valuable medicine, is composed of two caustic poisonous substances, viz. oil of vitriol, and barilla or soda. 4. The *Atmosphere* we breathe is composed of the same ingredients as that most violent and destructive liquid called aqua fortis, or nitric acid. 5. *Charcoal* is a solid substance which has never been reduced to a state of vapour; and the diamond, which is merely crystallized charcoal, is one of the hardest bodies in nature. *Sulphur*, in its simple state, is a solid substance, and requires a high temperature to maintain it in a state of vapour. But when carbon, the pure principle of charcoal, and sulphur are made to combine, the compound, instead of being solid, is a thin liquid, and cannot be frozen or rendered solid at any temperature; and instead of being difficult to vaporize, is one of the most evaporable of all liquids. 6. *Copper* is a soft metal; *tin* is still softer; but the compound of these metals is exceedingly hard. 7. Numerous examples of changes of properties occur in the combination of acids with alkalies. *Sulphuric acid*, for instance, and *soda*, possess caustic properties: the former is intensely acid, and converts the blue colour of vegetables into red; the latter has a pungent taste, and turns the blue colour of vegetables into green; on causing the two substances to combine, these properties of each are lost, and no

---

7. Give some examples of change of properties, as induced by chemical combination.

effect is produced by the compound on vegetable colours; they appear to have *neutralized* each other's properties.

8. *Change of Density.*—Chemical action is generally accompanied by *change of density.* Bodies which have combined, rarely occupy the same space which they filled when separate. 1. A pint of spirit and a pint of water, mixed together, occupy *less* space than two pints. 2. *Olefiant gas* consists of elements, which, when set free, expand to four times the bulk they occupied in the compound. 3. *Copper* is a light metal; *tin* is still lighter; but the compound is much heavier, bulk for bulk, than either. Glauber observes that if two balls of copper, and two of pure tin, of one and the same form and quantity, and of known weight, be melted together, and the melted mixture be poured into the mould of the first balls, scarcely three balls will be produced, though the weight of the four will be preserved. In these cases, the bulk is *diminished*, by combination. 4. Some *gases*, however, exhibit no change of density under similar circumstances; in the formation of some gases, there is an extraordinary *increase* of bulk. When water, for instance, is decomposed, and made to assume its elementary gaseous form, there is an increase of bulk nearly equal to 2,000 volumes. A cubic inch of water contains 662 cubic inches of oxygen, and 1325 cubic inches of hydrogen; its volume is therefore increased 1987 times by the decomposition. In some *metallic* compounds, the bulk is also *increased* by chemical action.

9. *Change of Temperature.*—When chemical action produces diminution of bulk, without a change of form, it is accompanied by a *change of temperature.* If a *pint of sulphuric acid* be mixed with a *pint of water*, the chemical action is so powerful as to raise the thermometer above the boiling point; the compound rises in temperature, owing to its having less capacity for heat than its ingredients possessed separately. But the intense heat which is sometimes evolved by chemical action, cannot be explained upon the principle of a change of specific heat. Change of temperature also occurs, when the combining bodies undergo a

---

8. State some cases in which chemical action is attended by change of density. Are there any instances of increase of bulk, produced by chemical action? What is the amount of this increase in the case of water, when decomposed?—9. Under what circumstances is change of temperature a result of chemical action? Give some instances.

change of form, as when a *gas* is condensed into a *liquid*, or a *liquid* into a *solid.* If water be poured upon lime, the two substances combine, the water loses its liquid form, and the lime swells, becomes hot, bursts, and is converted into what is called slaked lime. The production of *cold*, during combination, occurs only when heat is rendered insensible by a change of form, as on the conversion of a solid into a liquid, of a liquid into a gas. It is upon this principle that freezing mixtures are formed.

10. *Change of Form.*—Chemical action is attended by *change of form.* 1. *Gases* may form *liquids*, as when hydrogen and oxygen combine to form water. On applying a flame to a mixture of these gases, explosion takes place, attended with the evolution of great heat, and the elastic *gaseous* mixture is condensed into the *liquid*, water. 2. *Solids* may form *liquids*, as when carbon and sulphur combine, as has been already noticed. A nearly liquid substance is formed when equal parts of alum and sugar of lead are bruised together in a mortar. These substances contain a quantity of water, which is set free by the friction, and occasions the partial fluidity of the mixture. 3. *Liquids* may form *solids*, as when sulphuric acid is mixed with a solution of muriate of lime in water. Muriate of lime consists of muriatic acid and lime, and is readily soluble in water; sulphuric acid has a stronger affinity than muriatic acid for lime; it therefore combines with it, and forms a compound which is nearly insoluble in water, and which, in a spongy form, occupies the whole of the vessel. *Solids* are formed from *liquids* when a new substance *subsides* on mixing two solutions, as those of potash and of tartaric acid; the subsiding substance is insoluble in the liquid, and, in consequence of its being *thrown down*, is called a *precipitate.* 4. *Solids* may form *gases*, as when a vast quantity of gaseous matter is produced on igniting gunpowder, and attended by the phenomenon of *detonation;* or a gas may be more slowly disengaged by the action of a liquid upon a solid, and be attended by *effervescence*, as when marble is placed in hydrochloric acid. 5. A *gas* and a *metal* may form a *solid*, as when chlorine and sodium combine to form common salt.

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10. Illustrate the phenomenon of change of form as occasioned by chemical action, in the conversion of gases into a liquid; of solids into a liquid; of liquids into solids; of solids into gases.

11. *Change of Colour, Smell, Taste, and Sound.*—Chemical Action is frequently attended by *change of colour*. No uniform relation, however, exists between the colour of the compound and of its ingredients. Copper is of a *reddish-brown* colour, and tin is *white;* but the compound, instead of being of a paler reddish-brown colour, is *grey*. The brown oxide of copper generally gives rise to green and blue-coloured salts; while the salts of the oxide of lead, which is itself yellow, are for the most part colourless. The *white* metal zinc, and the *red* metal copper, when melted together, form the *yellow* compound brass. The vapour of iodine is of a *violet* colour; but it forms a *red* compound with mercury, and a *yellow* one with lead. Charcoal is the *blackest* of substances; sulphur is *yellow;* but the compound is *colourless* as water.—In this compound a new *smell* and *taste* are acquired; there is, in fact, not one point of resemblance to the elements of which it is composed. When nitric acid is made to act upon sugar, the *sweetest* of all substances, a powerful *acid*, the oxalic, is produced.—Another very remarkable change, produced by the combination of metals, is that of *Sound*. If three bells be cast from the same mould, one of copper nearly pure, the second of good tin, and the third of a mixture of both; the first will have a dull heavy sound, the second scarcely any sound at all, while the third will have a clear musical sound. Hence, bell-metal is a compound of tin and copper.

CAUSES WHICH MODIFY AFFINITY.

12. *Cohesion.*—Chemical Action takes place only between the minute *particles* of matter; it is, therefore, obviously opposed by *Cohesion*. 1. If a piece of iron and a piece of sulphur be brought together, no chemical action takes place. If the iron be reduced to filings, and the sulphur to powder, and both be mixed, still no change takes place. But, if this mixture be melted by heat, combination takes place, and a new substance is formed. Hence, it appears that *Cohesion is the antagonist of Affinity*, owing to its

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11. Give some examples of change of colour, of smell, of taste, of sound, as produced by chemical action.—12. How does cohesion prevent chemical action? Give an example. Illustrate the operation of chemical action in destroying cohesion. What form of body is most favourable for the exertion of affinity? Why so?

property of preserving bodies in a *solid* state; and that the *liquid* state is favourable to the exertion of Affinity, by permitting the closest approximation of the particles of matter. 2. On the other hand, *Affinity is the antagonist of Cohesion.* A piece of marble will not dissolve in water, for the cohesion among the particles of the marble is strong, and the affinity between the marble and the water weak. But if very strong vinegar be added, the greater affinity of this substance operates against the cohesion of the marble, which accordingly begins slowly to dissolve; if the resistance of cohesion be lessened by the application of heat, the force of affinity prevails still more by the diminution of the antagonist power, and the marble dissolves with facility. The *operation* of affinity is favoured by mechanical *division*, as well as by the application of *heat;* by the former means, the extent of surface is increased; by the latter liquefaction is produced. The best mode of ensuring chemical action is to reduce both substances to the *liquid* state by heat; in many cases it is sufficient if *one* of the substances is in a liquid state, as is proved by the facility with which water dissolves many salts and other solid bodies.

13. *Elasticity.*—When it is considered how cohesion counteracts the tendency of affinity by preserving the *solidity* of bodies, it might be supposed that the *gaseous* state is very favourable to chemical action. It is true that an air or a gas is totally devoid of cohesive attraction; but such bodies possess a property, of a very opposite nature indeed, but which equally antagonises the tendency of affinity, and is often overcome only by great difficulty. This is a repulsive agency, called *Elasticity;* its tendency is to keep the particles of a body at a distance from each other, so that combination is prevented. 1. Oxygen and hydrogen have a strong mutual affinity, but they may be preserved together for any length of time without combining. This is true of chlorine and hydrogen. But when the distance between the particles of such bodies is overcome by mechanical force, combination sometimes takes place with facility, and even with violence. 2. When this cannot be effected, many

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13. Why does elasticity prevent chemical action? By what means may oxygen and hydrogen be made to combine? What is meant by the combination of gases, when in a *nascent* state? How is it shown that elasticity is a decomposing agent? Show that the operations of heat, with reference to chemical action, are uniform.

gases are capable of combining readily while in their *nascent* state, that is, at the moment of their acquiring the gaseous form by the decomposition of some solid or liquid of which they formed an ingredient. 3. Elasticity is also a *decomposing agent.* Gaseous bodies, of feeble mutual attraction, as chlorine and nitrogen, which have been made to combine by considerable condensation, may be readily decomposed; a slight elevation of temperature, or the contact of a substance which has an affinity for either of them, causes an immediate explosion. For the same reason, all compounds which contain a *volatile* and a *fixed* principle, are liable to be decomposed by a high temperature. 4. Some of the decompositions formerly ascribed to the sole influence of elective affinity, may be attributed to elasticity. If three substances be mixed together, capable of producing two compounds, one of which is more volatile than the other, the *more volatile* compound will generally be formed and driven off by the agency of heat. Some cases of double decomposition may be similarly explained. From what has been said in this, and in the preceding paragraph, it appears that the influence of *Heat* varies in respect to chemical action; that it sometimes *increases*, at other times *diminishes*, the force of affinity. Its modes of action are, however, consistent with each other:—first, it favours affinity by diminishing cohesion; secondly, it prevents composition, by keeping the particles of bodies at a distance from each other; or, by producing expansion, it tends to separate from each other substances already combined.

14. *Quantity of Matter.*—The force of affinity is much influenced by what is called *Quantity of Matter*. 1. Decomposition is more easily effected in proportion to the larger quantity of any ingredient combined. Thus, oxygen combines with lead in three different quantities; the compound which contains the largest quantity of oxygen is easily decomposed by the action of heat; a higher temperature is required to decompose the second compound; and the strongest heat of a furnace will not decompose the last. It may therefore be stated, that the larger the quantity of any ingredient combined with another, the more easily is a portion of it separated. 2. In forming *solutions*, it is found

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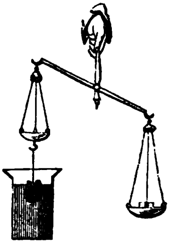
14. Give an instance in which decomposition is more easily effected in proportion to the larger quantity of any ingredient combined. Explain the influence of quantity of matter in forming solutions; and in favouring chemical action.

that equal quantities of the substance to be dissolved, become successively more difficult of solution, until the affinity between the solvent and the solvend is entirely satisfied; the solution is then said to be *saturated*, and no more can be dissolved, unless the temperature be raised. It may therefore be stated that the less the quantity of a substance combined with another, the more readily does an additional quantity enter into combination. 3. The larger the quantity of a substance employed in chemical operation, the more speedily will the action be effected. Thus, in separating an acid from a compound by means of an alkali, a larger quantity of this alkali is employed than is necessary to saturate the acid; by this means every particle of the substance to be decomposed is subjected to the action of the alkali. Very different products are, however, sometimes obtained according to the quantity of the substance used.

15. *Gravity.*—The influence of *Gravity* resembles that of cohesion in masses, in preventing that intimate mixture which favours chemical action. Hence, when two bodies differ in specific gravity, their combination is opposed. Oil floats on water, and refuses to combine with it, being specifically lighter. Salt sinks in water, being heavier; and it is only by agitating the solution, that the salt can be equally diffused throughout it. In melting together metals of different specific gravities, it is necessary to stir the mixture, to prevent the heavier metal from subsiding to the bottom.

16. *Specific Gravity.*—The specific gravity of a body is its *density*, compared with the density of another body which is assumed as the standard. This standard is pure water, at the common temperature. 1. In order to determine the specific gravity of a *solid*, it is necessary, first, to weigh it in common scales in the air, and then to weigh it in water by the apparatus represented in the figure. A body, so immersed, *loses* of its weight a quantity precisely equal to the weight of its own bulk of water; and hence, by comparing this weight

Fig. 1.



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15. How does gravity modify chemical action? Give some instances of its counteracting power.—16. What is meant by specific gravity? How is the specific gravity of a solid body ascertained? how, that of a liquid? how, that of a gas?

with the total weight of the solid, its specific gravity is ascertained. The rule, therefore, is to divide the total weight in air by the *loss* of weight in water; the quotient gives the specific gravity. If, for instance, a piece of lead weighs, in the *air*, twenty-two grains, and only twenty in *water*, the loss is two grains, and this is exactly equal to the weight of a quantity of water equal to the lead in size. As 2, therefore, the loss of weight in water, is to 22, the total weight in air, so is 1, the standard of unity, to 11, the specific gravity of lead. 2. The specific gravity of a *liquid* body is more easily ascertained, by filling a small bottle of known weight with it, and with water, successively, and weighing them. 3. The specific weight of a *gaseous* body is ascertained by comparing it with atmospheric air. The first step is to find the weight of a given volume of air. For this purpose a flask provided with a stop-cock, is weighed when full of air; the air is then withdrawn by means of the air-pump, and the flask is again weighed; the difference between the two weights is that of the volume of air. By similar means the weight of any gas may be found, and its specific gravity, with reference to atmospheric air, be determined.

17. *The Imponderables.*—The influence of the *Imponderables* upon chemical action has been sufficiently explained in the First Book of Heat, Light, and Electricity. The last of these agents is frequently employed to effect the combination, and sometimes the decomposition, of gaseous bodies. It appears to act by the heat which is evolved.

LAWS OF CHEMICAL COMBINATION.

18. Affinity being a property probably possessed by all bodies, it is important to ascertain whether there is any limit to its operation, whether combination satisfies or weakens its tendency, whether there are any fixed laws by which chemical combination is regulated. 1. Some bodies are found to unite in *any* proportion in which they may be mixed together, as water and alcohol. Others unite in every proportion up to a certain limit; thus, water will dissolve salt in any quantity, up to the saturating point,

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17. What appears to be the mode of action of the imponderables in causing chemical action?—18. In what respect do bodies vary in reference to their combining powers?

but has no effect upon any additional quantity. A hundred grains of water will dissolve any quantity of sea-salt which does not exceed forty grains; after this, the cohesion of the salt prevails against its affinity for the water. In all these cases, the affinities are feeble, and the properties of the compounds partake more or less of those of their elements. 2. But there are bodies which combine only in one, or in a few fixed proportions; and their compounds lose, more or less entirely, the properties which characterized their elements. These are the compounds which exhibit the characteristic effects of chemical action. Their combination is regulated by the following *laws*:—

19. *Law* 1.—*The composition of all bodies, whether formed by nature or by art, is fixed and invariable; their elements are found to exist always in the same relative quantities.* 1. A piece of marble always contains the same relative qualities of carbonic acid and lime, from whatever part of the world it be procured. 2. If a portion of lime be exposed for a long time to the atmosphere, it absorbs from it a quantity of carbonic acid; if the weight of the lime be represented by 100, the weight of the carbonic acid absorbed will be 78½; if exposed to the atmosphere for an unlimited period, not another particle of the acid will be absorbed. These are, therefore, the *fixed proportions* in which these elements exist in marble, and in limestone; and these elements are found associated in the same proportions in various other minerals. 3. Water consists of one part of hydrogen and eight parts of oxygen, by weight; and so invariable is this rule, that water cannot be formed by any other proportions of these elements. 4. Salt, whether obtained from mines, lakes, or the ocean, always consists of thirty-six parts of chlorine gas and twenty-four parts of the metal sodium. 5. Sulphuric acid is always composed of sixteen parts of sulphur and twenty-four parts of oxygen; if these elements were made to combine in other relative proportions, some *other* compound might be formed, but *not* sulphuric acid. This law is of the utmost importance, and constitutes the very basis of Chemistry.

20. *Law* 2.—*The relative quantities in which bodies combine, may be expressed by proportional numbers.* Thus,

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19. State some instances in proof of the first *law* of chemical combination, that the composition of all bodies is fixed and invariable.—20. What is the meaning of the word equivalent? What are the equivalent numbers of the elements of water, and of potash?

8 parts of oxygen combine with 1 part of hydrogen, with 16 parts of sulphur, with 35·4 of chlorine, with 39·6 of selenium, or with 108 of silver. When any of these bodies combine with each other, they combine either in the same quantities as above stated, or in some *multiple* of those quantities, as will be noticed in the following law. Thus, 16 parts of sulphur combine with 1 of hydrogen, with 35·4 of chlorine, with 39·6 of selenium, or with 108 of silver. And so of the other bodies.—Upon the principle of this law, Wollaston applied the term *Equivalent* to the combining proportions of elementary, and of compound, substances required to neutralize each other; the combining proportion of one body being considered as equivalent to that of another body, and capable of being substituted for it in combination. Thus, 8 is the equivalent of oxygen, 16 of sulphur, and in these proportions they combine; but if it is desired to produce combination between oxygen and silver, the numbers will be 8 and 108; and the number 108, which represents silver, is considered to be equivalent to the number 16, which represents sulphur; for either of them combines with the same proportional number, or equivalent, of oxygen.—This law applies not only to *elementary*, but also to *compound*, substances. Water consists of oxygen 8, and hydrogen 1; the equivalent of *water* is therefore 9. Potash consists of potassium 39, and oxygen 8; the equivalent of *potash* is therefore 47. If it be desired to produce combination between these commands, the combining equivalents will be 47 + 9, and the equivalent of the new compound 56.

21. *Law* 3.—*When a body combines with another body in more than one definite proportion, the quantity of one of them in the different compounds is found to bear a very simple ratio to that of the other.* 1. A body may combine with from one to six equivalents of another; in such cases, the combining proportion of the second body is always some *multiple* of the first equivalent. Thus, 8 of oxygen combines with 16, or with 32, of sulphur, but with no intermediate quantity; with 108, or with 216, of silver; and so with all other substances. 2. A body may combine with half an equivalent of another body, with one equivalent, with one and a half, with two equivalents, with two and a

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21. What is meant by combination in multiple proportion?

half, &c. Thus phosphorus combines with half an equivalent of oxygen, or 4, to form one compound; with an equivalent and a half, or 12, to form a second compound; with two and a half, or 20, to form a third.

22. *Chemical Equivalents.*—Chemical equivalents merely represent the relative quantities of substances which combine together, as referred to some standard of comparison. Hydrogen is generally assumed in this country as the standard, the number assigned to it being 1, or *unity.* Dr. Thomson makes oxygen 1, so that hydrogen is eight times less than unity, or ·125. Wollaston made oxygen 10, so that hydrogen would be 1·25. It is of little importance which plan is adopted, provided the relation be strictly observed. The hydrogen may be converted into the oxygen scale, by dividing the former by 8; the oxygen into the hydrogen, by multiplying the former by the same number.

Chemical Equivalents of Elementary Substances.

Elements.	Equivalents.	Elements.	Equivalents.	Elements.	Equivalents.
Aluminium	13·7	Iodine	126·3	Rhodium .	52·2
Antimony .	64·6	Iridium	98·8	Selenium .	39·6
Arsenic . . .	37·7	Iron	28	Silicium . .	7·5
Barium . . .	68·7	Lead	103·6	Silver. . . ,	108
Boron	10·9	Lithium	10	Sodium . .	23·3
Bromine . .	78·4	Magnesium .	12·7	Strontium	43·8
Cadmium . .	55·8	Manganese .	27·7	Sulphur . .	16·1
Calcium . .	20·5	Mercury	202	Tellurium	32.3
Carbon	6·12	Molybdenum	47·96	Thorium .	59·6
Cerium . . .	46	Nickel	29·5	Tin	58·9
Chlorine . .	35·42	Nitrogen . . .	14·15	Titanium .	24·3
Cromium . .	28	Osmium	99·7	Tungsten .	94·8
Cobalt	29·5	Oxygen	8	Vanadium	68·6
Copper . . .	31·6	Palladium . .	53·3	Uranium .	217
Fluorine . .	18·68	Phosphorus .	15·7	Yttrium .	32·2
Glucinium	17·7	Platinum . . .	98·8	Zinc	32·3
Gold	199·2	Potassium . .	39·15	Zirconium	33·7
Hydrogen .	1				

22. What substances are employed as standards of comparison, in forming chemical equivalents? What are the numbers of these substances respectively?

23. *Atomic Theory.*—It is possible to conceive that a grain of sand may be divided into a million parts, and each of these into a million more, and so on *ad infinitum*. It may, however, be true that a grain of sand cannot be divided into more than a certain number of parts, each of which, though invisible under our microscopes, possesses such cohesive power as to resist further division. Whether matter be infinitely divisible, or consist of ultimate particles called *Atoms*, is still a disputed point. The latter opinion was assumed by Dalton, as the most satisfactory method of explaining the foregoing laws of chemical combination; it forms the basis of what is called the *Atomic Theory*. According to this theory—

(1.) All bodies consist of *ultimate atoms*, which are of the same size and shape in the same body, but which differ in *weight*, in different bodies. The weight of an atom of oxygen is eight times as great as that of an atom of hydrogen, and half as great as an atom of sulphur.

(2.) Chemical combination takes place between the *atoms* of bodies. One atom of one body may combine with one or more atoms of another body: thus, one atom of hydrogen combines with one atom of oxygen to form water; two atoms of oxygen combine with one atom of sulphur to form sulphur*ous* acid; while three atoms of oxygen combine with one atom of sulphur to form sulphur*ic* acid. Nitrogen and oxygen combine in the several proportions of from one to five atoms of the latter, to one atom of the former, gas.

(3.) From these cases it appears that the law of multiple proportion, already described, is a necessary consequence of the *atomic theory*. The term *atom* is, accordingly, frequently used in the same sense as the term *equivalent*: water may be described as consisting of one atom of hydrogen, and one atom of oxygen, as well as of one equivalent of each of these elements. The numbers expressing the proportions in which bodies combine, will also express the relative weights of atoms; these numbers are, therefore, often termed *atomic weights*.

24. Compounds of which oxygen forms a part, are called *Acids* or *Oxides*, according as they do, or do not, possess

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23. What is the basis of the atomic theory? What is an atom? What are the atomic proportions of the ingredients of water, and of sulphuric acid?—24. What is meant by the terms acid and oxide.

acidity: oxygen and sulphur form a compound with *acid* properties; oxygen and iron form an *oxide*, without acid properties.

25. The term *Acidity* is applied to bodies which have the power of reddening the blue colours of vegetables; that of *Alkalinity* to bodies which turn vegetable blue colours to green, and yellow colours to brownish red; the former bodies are termed *acids*, the latter *alkalies*. The presence of an acid or of an alkali in solution, may be therefore detected by means of vegetable *colouring matters;* these are termed *tests*, from their *testing* or distinguishing the chemical composition of bodies; or *re-agents*, from their *re-acting* upon the elements of bodies. 1. By means of an infusion of *red cabbage*, a blue colouring matter is obtained, which turns *red* by the action of acids, and *green* by the action of alkalies. The colouring matter of violets may be used for the same purpose. 2. *Litmus* is a blue colouring matter prepared from the *Lichen Rocella*. A slip of paper tinged with this substance, is more readily affected by *acids* than the colouring matter of cabbage, but is not turned to green by alkalies. But if previously reddened by acids, it becomes a valuable test for alkalies, which restore its blue tint. 3. *Turmeric* is a yellow colouring matter prepared from the *Curcuma longa*. A slip of paper stained with a decoction of this substance, detects the presence of *alkalies* by forming with them a brown compound. It is not affected by acids; but, if previously rendered brown by an alkali, it is a valuable test for acids, which restore its original yellow tint.

26. The names of the *Acids* are derived from the substances with which oxygen combines, and these substances are termed the *bases:* in sulphuric acid, sulphur is the base; in carbonic acid, carbon. A base may combine with oxygen in more proportions than one, and form acids of different degrees of strength; these proportions are indicated by a different termination of the name of the acid; that in which the larger quantity of oxygen exists, terminates in *ic*, as sulphur*ic* acid; that in which the smaller quantity exists, in *ous*, as sulphur*ous* acid.

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25. How are the acidity and alkalinity of bodies tested?—26. What is a base? How are the proportions of oxygen which combine with a base, determined by the name?

27. Acids combine with metallic oxides, or with alkaline bases, and form compounds called *Salts*, the names of which are contrived so as to indicate the substances composing them. The acids terminating in *ous*, form salts which terminate in *ite;* those which end in *ic*, form salts which end in *ate;* thus sulphur*ous* acid combines with potassa, forming sulph*ite* of potassa; sulphur*ic* acid forms with the same base, sulph*ate* of potassa. The names of all the salts are thus made to indicate their ingredients.

28. When a simple non-metallic substance combines with another substance of this class, with a metal, or with a metallic oxide, the name of the compound terminates in *uret*, as in sulph*uret* of mercury, carb*uret* of iron. Sometimes the different sulphurets or oxides are distinguished by the *colour* of the compounds, as the black and the red sulphurets of mercury, the black and the red oxides of iron.

29. The non-acid compounds which are formed by oxygen, chlorine, iodine, bromine, and fluorine, terminate in *ide*, as the ox*ide* of zinc, chlor*ide* of mercury, iod*ide* of lead, &c. Different *degrees* of oxidation are denoted by prefixing Greek numerals, as *prot*-oxide, *deut*-oxide, *trit*-oxide; or Latin numerals, as *bin*-oxide, *ter*-oxide; the term *per*-oxide is generally applied to the highest degree of oxidation. The Latin term *sesqui*, one and a half, denotes that the elements exist in a compound in the ratio of 1 to 1½, as the *sesqui*-carbonate of ammonia, containing one equivalent and a half of acid.

30. The different salts formed of the same ingredients were formerly divided into *neutral*, *super*, and *sub* salts. In the first, the base is perfectly saturated with the acid, and the compound has no characteristic properties of either ingredient, as in the sulphate of potassa. In the second, the properties of the acid predominate, as in super-tartrate of potassa. In the third, the properties of the base predominate, as in sub-borate of soda. A *double salt* is a compound of two salts, as the tartrate of potassa and soda, which is considered as consisting of tartrate of potassa and tartrate of soda. A *triple* salt denotes a compound of three salts.

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27. What is a salt? How are salts named, with reference to the acids which enter into their composition?—28. What is meant by a sulph*uret* and a carb*uret*?—29. How are the non-acid compounds named?—30. What is meant by the terms *neutral*, *super*, and *sub*, as applied to salts? What is a double, and what a triple, salt?

31. There are several terms employed to express *solution* of solid matters, as performed under various circumstances; these terms relate to cases in which the whole of the solid matter, placed in the liquid, is not dissolved, a portion of it only being extracted, and passing into the liquid state. When a substance to be subjected to the action of water has hot water merely poured upon it, this is called *infusion*. When heat is applied to the liquid for some time, this is called *decoction*. When cold or warm water is poured on the substance, and allowed to remain for some time, this is termed *maceration*. When a saline matter is extracted by means of water from a solid mass which consists of both soluble and insoluble ingredients, the process is termed *lixiviation*. When a substance is subjected for some time to the action of a solvent, it is said to undergo *digestion*. A liquid which acts the part of a solvent, without changing the nature of the substance to be dissolved, is termed a *menstruum*.

32. The vaporization and subsequent condensation of liquids constitute the process of *distillation*. The subjection of bodies to a red heat in close vessels, and the collection of the products, constitute *destructive distillation*. The process by which volatile substances are raised by heat, and again condensed into the solid form, is called *sublimation;* it is, in fact, dry distillation.

33. When solids are dissolved in a liquid, as water, for the purpose of procuring crystals, a portion of the liquid is often chemically combined with the crystals; this is termed *water of crystallization*. Salts containing this water may melt on the application of heat, and are then said to undergo *watery fusion;* or they may melt after the water has been expelled, and are then said to undergo *dry fusion*. When a salt, or other substance attracts moisture from the air, and melts, the liquefaction is termed *deliquescence;* when the moisture is removed from a salt by the action of a dry atmosphere, attended by the production of a powdery-looking substance, the process is termed *efflorescence*. The separation or splitting of crystals on the application of heat, is

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31. Explain the terms infusion, decoction, maceration, lixiviation, digestion, and menstruum.—32. What is meant by distillation and sublimation?—33. What is meant by water of crystallization; by watery and by dry fusion; by deliquescence, by efflorescence, and by decrepitation?

accompanied by a crackling noise, which is termed *decrepitation.*

34. *Arrangement of Elementary Bodies.*—The *Elementary Bodies* may be divided into the non-metallic, and the metallic.—1. The *Non-metallic* bodies are twelve in number. Some of these agree in certain properties, but differ remarkably in others. These have a tendency to combine, not only with each other, but with almost all other substances; and their union is usually accompanied by the evolution of light and heat; hence, they are commonly called *supporters of combustion.* Some of the others, instead of supporting the combustion of other substances, are themselves combustible. From their property of generally forming acids, when combined with the supporters of combustion, they have been termed *acidifiable bases.*—2. The *Metallic* bodies are forty-three in number. They all combine with oxygen, and the results of their combination with this element furnish a means of distinguishing them into groups. Three of them, when combined with oxygen, form compounds which possess alkaline properties, and are therefore termed *metallic bases of the alkalies.* The next four form compounds which resemble earths, but are similar to the alkalies in their action; these compounds are called *alkaline earths,* and the metals which yield them are called *metallic bases of the alkaline earths.* The next six yield, by combination with oxygen, the pure earths, and are therefore called *metallic bases of the earths.* The remaining metals, when combined with oxygen, yield neither alkalies nor earths. Many of them, like some of the non-metallic elements, form acids with this element, and are termed *acidifiable bases.* They may be divided into groups according to the effects which they produce on water at a red heat, and to the effects produced by heat upon their oxides, or combinations with oxygen. Thus, seven of them, at a red heat, decompose water. Fifteen of them do not decompose water at any temperature, nor can their oxides be reduced to the metallic state by the sole action of heat. The remaining eight admit of having their oxides decomposed by a red heat. These divisions, together with the names of the elementary substances themselves, are presented in the following table:—

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34. Give a general index of the arrangement of the elementary bodies.

I. Non-metallic Bodies.

1. *Supporters of Combustion.*

1. Oxygen
2. Chlorine
3. Bromine
4. Iodine
5. Fluorine

2. *Acidifiable Bases.*

6. Hydrogen
7. Nitrogen
8. Sulphur
9. Boron
10. Selenium
11. Phosphorus
12. Carbon

II. Metallic Bodies.

1. *Metallic bases of the Alkalies.*

13. Potassium
14. Sodium
15. Lithium

2. *Metallic bases of the Alkaline Earths.*

16. Barium
17. Strontium
18. Calcium
19. Magnesium

3. *Metallic bases of the Earths.*

20. Aluminium
21. Thorium
22. Glucinium
23. Zirconium
24. Yttrium
25. Silicium

4. *Metals which decompose water at a red heat.*

26. Manganese
27. Zinc
28. Iron
29. Tin
30. Cadmium
31. Cobalt
32. Nickel

5. *Metals which do not decompose water at any temperature, and the oxides of which are not reduced to the metallic state by the sole action of heat.*

33. Arsenic
34. Chromium
35. Vanadium
36. Molybdenum
37. Tungsten
38. Columbium
39. Antimony
40. Uranium
41. Cerium
42. Bismuth
43. Titanium
44. Tellurium
45. Lantanum
46. Copper
47. Lead

6. *Metals, the oxides of which are decomposed by a red heat.*

48. Mercury
49. Silver
50. Gold
51. Platinum
52. Palladium
53. Rhodium
54. Osmium
55. Iridium

OF THE NON-METALLIC ELEMENTS.

CHAPTER II.

OF OXYGEN.

35. *General Remarks.*—Oxygen, in its *elementary* state, is a *gas*. It is one of the few elementary substances which occur naturally in the gaseous form; in this state, and uncombined, it constitutes about one-fifth of atmospheric air. In a state of *combination*, this element occurs in such vast abundance as to form upwards of one half of the globe. Oxygen exists in the *liquid* form in water, in which it occurs in combination with hydrogen in the proportion of one volume of the former to two volumes of the latter gas. Oxygen is found also in the *solid* state: most of the mineral bodies forming the crust of the earth, contain more or less oxygen; and it exists, as an elementary principle, in almost all the products of the animal and vegetable kingdoms. Oxygen is, perhaps, the most important of all the elements; from its proneness to enter into composition, it is constantly operating upon, and modifying, every thing in nature. The complicated apparatus, connected with the respiration of animals, is obviously constructed with reference to the properties of oxygen as it exists in the atmosphere. Oxygen was discovered in 1774 by Priestley; its name denotes that it is a *generator of acidity*.

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35. What is oxygen? In what proportion does it enter into the composition of atmospheric air? and of water? In what forms is it found in a solid state? In what respect is oxygen the most important of all the elements? What is the meaning of the term oxygen?

36. *Mode of procuring Oxygen.*—Oxygen gas is generally procured from some compound containing it, by the action of heat. A large quantity of perfectly pure oxygen may be obtained by the following process. Half an ounce of the salt called *chlorate of potassa* is placed in a Florence oil flask, furnished with a perforated cork, into which a bent glass tube is fixed, as shown in the figure. The flask is placed upon a chemical stand, and heat is applied by means of a spirit lamp. The salt melts, though it contains no water, and, when nearly red hot, gives off an abundance of oxygen gas. The gas passes through the glass tube, and enters the glass vessel, or *receiver*, which had been previously filled with water, and inverted upon the shelf of a pneumatic trough.* In this way the chlorate of potassa parts with all the oxygen it possessed, amounting to 37 per cent. of its weight; and a white hard salt, called chloride of potassium, is left in the flask. The *changes* which take place in this experiment, are the following: chlorate of

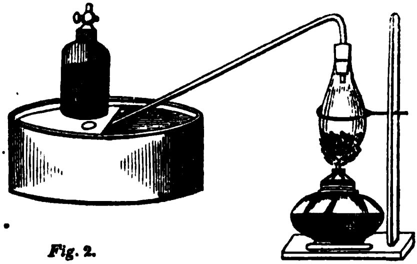

Fig. 2.

* The *pneumatic trough* is a vessel made of tinned iron, and capable of holding a large quantity of water. At the depth of about two inches from the top, a shelf is fixed horizontally to both sides of the trough, and extends to half its breadth, so that there is a large open space on one side. The shelf is perforated with a few holes. When the trough is to be used, it must be filled with water to a little above the level of the shelf, which must always be completely covered with the liquid. When it is required to collect a gas, a jar or receiver must be filled with water, and inverted over one of the holes on the shelf. As most gases pass through water without mixing with it, and are lighter than water, they rise above its surface, and may be collected into a receiver, as shown in the figure. As the gas ascends, the water is forced down until it is all expelled, and the receiver is consequently filled with gas.

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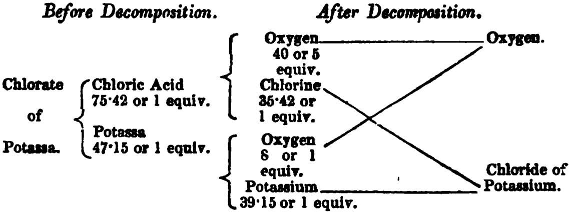
36. Explain one of the processes for procuring oxygen. What is the pneumatic trough? Enumerate the changes which take place in this process.

potassa consists of chloric acid and potassa; of these, chloric acid consists of oxygen and chlorine, and potassa consists of oxygen and potassium. All the oxygen escapes, by the application of heat, and the chlorine of the chloric acid combines with the potassium of the potassa, forming chloride of potassium. The process may be illustrated by the following *diagram:*



37. *Properties of Oxygen Gas.*—Pure oxygen gas is a permanently elastic fluid, without colour, taste, or smell. It has neither acid nor alkaline properties. It is a non-conductor of electricity, and the most perfect negative electric. It is sparingly absorbed by water, 100 cubic inches of this liquid dissolving only 3 or 4 of the gas. It refracts light very feebly, and is not chemically affected by the imponderables. Its *specific gravity* is rather greater than that of air.

38. Oxygen is a *supporter of combustion*. All bodies which burn in atmospheric air, burn with much greater brilliancy in this gas. If a lighted wax taper attached to a copper wire be blown out, and plunged into a vessel of oxygen gas, while a spark of light remains in the wick, it is instantly rekindled into flame with a slight explosion; and this may be repeated, so long as a spark remains in the wick. A piece of wood, which has been lighted, burns with flame in this gas; and red-hot charcoal throws out dazzling sparks. Burning sulphur emits an azure blue flame of considerable intensity; and phosphorus burns with a light too intense for the eye to bear. Even iron wire and steel are fused and burned in oxygen gas, throwing out numerous

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37. What are the general properties of oxygen? How is it affected towards electricity?—38. Give some instances in proof of oxygen being a supporter of combustion.

sparks, and occasionally allowing a globule of fused oxide to fall; these globules are so intensely hot, that they retain a red heat for some time under the surface of water, and burn into the substance of an earthenware plate, upon which they are allowed to fall.

39. Oxygen is necessary for *Respiration.* No animal can exist in an atmosphere from which Oxygen has been excluded. Its effect is to change the dark colour of the venous blood into a bright vermilion red; and it is produced in the lungs of living animals, or by agitating in a vessel with the gas a portion of blood drawn from a vein. Respiration is, in fact, a kind of *slow combustion:* in proportion as oxygen is consumed by these processes, respiration ceases, and flame is extinguished. The continued respiration of unmixed oxygen is, however, injurious to life; it stimulates and quickens the vital powers for a certain time, after which it produces debility and death.

40. Oxygen *combines*, in one or more proportions, with all the other elements, except fluorine, and forms compounds called *oxides;* the process of combination is termed *oxidation.* Many of its compounds possess *acid* properties, particularly those which contain more than one equivalent of oxygen to one of the other elements in combination. These compounds are most readily formed with the non-metallic elements, as carbonic acid with carbon, sulphuric acid with sulphur, phosphoric acid with phosphorus. Many of its compounds are formed with single equivalents of various metallic bodies; these possess *alkaline* properties, and are called *bases,* as potash, formed by oxygen and potassium; lime, by oxygen and calcium, &c. Some of its compounds are neither acid nor alkaline, and are therefore called *neutral* bodies, as when oxygen combines with hydrogen and forms water. *Oxygen acids* combine with *oxygen bases*, and form neutral *salts*, as carbonic acid with lime, forming the carbonate of lime.

41. *Theory of Combustion.*—The term *Combustion* denotes the combination of oxygen with some other body,

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39. What is the effect of oxygen in the function of respiration? What would be the effect of exhaling pure oxygen? Is there any relation between respiration and combustion?—40. With what elements will oxygen combine? What are the names of the compounds which it forms, and what are the properties of these compounds, respectively?—41. Explain the theory of combustion, and illustrate the theory by the chemical process of burning a candle or lamp. What result is obtained by burning a combustible body in a jar of oxygen?

attended by the evolution of heat and light; the latter body is called a *combustible*, and, instead of undergoing oxidation, is said to be *burned;* the oxygen which combines with it, and supports the burning of it, is called a *supporter of combustion.* This may be illustrated by the chemical process of the *burning of a candle or lamp.* The wick is lighted by a piece of burning paper or wood; by this means the particles of fat or oil immediately contiguous to the flame are heated sufficiently to be decomposed into inflammable *gaseous* matter; this combines with the oxygen of the surrounding air, and produces the phenomenon of *flame;* the flame gives out sufficient heat to decompose another portion of the fat or oil; and thus the process continues until the whole of the candle or oil is exhausted. On burning any combustible substance in a jar of oxygen, a considerable quantity of the gas disappears, while the weight of the combustible increases in exact proportion to the loss of the oxygen; a combination has thus taken place between the gas and the combustible, and an *acid* or an *oxide* is formed; this compound may be again resolved, by chemical action, into its constituent elements.

42. The *Economical Applications* of the heat evolved by combustion are of the highest importance, as will be seen in the following cases, enumerated by Sir J. Herschel, in his 'Discourse on the Study of Natural Philosophy.'

(1.) 'It is well known to modern engineers, that *there is virtue* in a bushel of coals, properly consumed, to raise seventy millions of pounds weight a foot high. This is actually the *average* effect of an engine at this moment working in Cornwall. Let us pause a moment, and consider what this is equivalent to in matters of practice.

(2.) 'The Menai Bridge, one of the most stupendous works of art that has been raised by man in modern ages, consists of a mass of iron, not less than four millions of pounds in weight, suspended at a medium height of about 120 feet above the sea. The consumption of seven bushels of coals would suffice to raise it to the place where it hangs.

(3.) 'The great pyramid of Egypt is composed of granite. It is 700 feet in the side of its base, and 500 in perpendicular

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42. What useful effect may be obtained from the combustion of a bushel of coals? State some other economical applications of the heat evolved by combustion.

height, and stands on eleven acres of ground. Its weight is, therefore, 12,760 millions of pounds, at a medium height of 125 feet; consequently it would be raised by the effort of about 630 chaldrons of coal, a quantity consumed in some foundries in a week.

(4.) 'The annual consumption of coal in London is estimated at 1,500,000 chaldrons. The effort of this quantity would suffice to raise a cubical block of marble, 2200 feet in the side, through a space equal to its own height, or to pile one such mountain upon another. The Monte Nuovo, near Pozzuoli (which was erupted in a single night by volcanic fire) might have been raised by such an effort from a depth of 40,000 feet, or about eight miles.'

43. *Experiments.*—(1.) Put an ounce or two of the black oxide of manganese into a small glass retort, pour a little concentrated sulphuric acid upon it, and apply the heat of a lamp. Oxygen gas will be disengaged in abundance.

(2.) If the leaves of a plant, fresh gathered, be placed in a vessel of water, and exposed to the sun, very pure oxygen gas may be collected.

(3.) If a glow-worm be placed within a jar of oxygen gas, in a dark room, the insect will shine with much greater brilliancy than in atmospheric air, and will appear to be stimulated to unusual activity.

(4.) If phosphorus be exposed to the atmospheric air, it soon becomes white, and afterwards acquires a dark-brown colour. It has, in fact, abstracted oxygen from the air, combined with it, and is now an *oxide* of phosphorus.

(5.) If pure nitric acid be poured on the black oxide of manganese, no solution will be effected. Add a little sugar, and this substance will abstract a portion of the oxygen from the oxide of manganese; the acid will then be enabled to dissolve the metal.

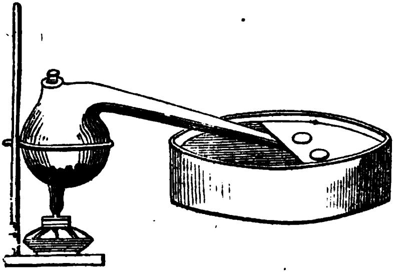
(6.) When silver has been dissolved in aqua fortis, the refiner can recover the silver by placing plates of copper in the solution. The copper absorbs oxygen from the silver, and the latter is precipitated in the metallic state. All metals can de-oxidize gold and silver: copper will take oxygen from mercury, and iron will reduce an oxide of copper.

CHAPTER III.

OF HYDROGEN.

44. *General Remarks.*—Hydrogen, in its *elementary* state, is a *gas;* it is, however, found in nature only in a *combined* state. It occurs most generally, and abundantly, in combination with oxygen, in the form of *water*, and it enters into the composition of almost every organic substance. In reference to organized beings, therefore, hydrogen ranks next in importance to oxygen. It differs from oxygen in not being, in its elementary state, necessary to life; indeed, hydrogen is actually incompatible with the existence of animals, if not of vegetables. From the inflammable nature of Hydrogen, it was formerly called *inflammable air;* its present name denoting *generator of water*, has reference to the formation of that liquid from the combination of this gas with oxygen.

Fig. 3.



45. *Mode of procuring Hydrogen.*—Hydrogen is procured by decomposing water by means of iron, zinc, or some other metal. The following is the simplest mode of obtaining this gas. A glass *retort* must be procured. The shape of this vessel is represented in fig. 3. The retort

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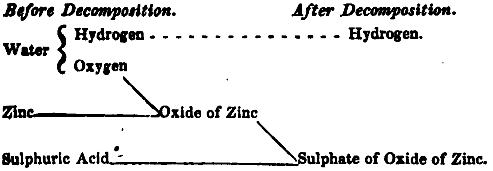
44. What is hydrogen? In what state does it occur in nature? In what important respect does it differ from oxygen?—45. How may hydrogen be procured? What changes take place during this process?

should be *tubulated;* that is, it must be furnished with a mouth at the upper part, to which a cork, or an air-tight stopper of ground glass, is fitted. A number of small iron nails, or small pieces of zinc, are to be introduced by the tubulature; water is then poured in, in much greater quantity than is sufficient to cover the metal; and to this is added about the same weight of sulphuric acid as that of the nails. Effervescence immediately commences, owing to the extrication of hydrogen gas, which is expelled through the *beak* of the retort, and received into a glass jar or receiver, inverted, as in fig. 2, full of water, upon the shelf of the pneumatic trough. By adding more sulphuric acid, when the effervescence becomes feeble, fresh supplies of hydrogen may be procured, and any number of bell-glasses may thus be filled with the gas. The first portions of the gas, being mixed with the common air of the retort, and therefore impure, should be allowed to escape. One ounce of zinc will cause the evolution of 615 cubic inches of hydrogen. The *changes* which occur during the process are shown in the following *diagram:*



46. *Properties of Hydrogen.*—Pure hydrogen is a permanently elastic fluid, without colour, taste, or smell. It cannot support respiration, for an animal soon perishes if confined in it; when taken into the lungs in a large dose, it produces a shrill, squeaking sound of the voice. It has neither acid nor alkaline properties. It is a non-conductor of electricity, and occupies the lowest position in the series of negative electrics. It is sparingly absorbed by water, 100 cubic inches of this liquid dissolving about one and a half of the gas. It is a powerful refractor of light.

47. Hydrogen gas is the *lightest substance in nature.* It

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46. What are the general properties of hydrogen? How is it affected with regard to electricity?—47. What is the lightness of hydrogen, as compared with that of oxygen, and of atmospheric air? How may its lightness be exhibited?

is 16 times lighter than oxygen, and 14·4 times lighter than atmospheric air; 100 cubic inches of hydrogen gas weigh only 2·14 grains. The *lightness* of hydrogen gas may be exhibited in an amusing manner by the following experiments. 1. A bell-glass, furnished with a stop-cock, may be filled with hydrogen by means of the water trough, as represented by fig. 4; to this is fixed a bladder, also provided with a stop-cock. On opening both the stop-cocks, and lowering the bell-jar into the water, the gas is forced up into the bladder, which may thus be filled, and removed from the jar. A tube may then be adapted to the mouth of the bladder, and bubbles formed by dipping its extremity into soap lather; these bubbles rise rapidly into the air, and may be fired by the application of flame as they rise. If a little balloon of oiled silk be substituted for the bladder, it will rise into the air, owing to the low specific gravity of the gas. 2. If two bell-glasses be filled with hydrogen gas, and placed, the one with its open mouth upwards, the other with its mouth downwards, the gas will have entirely escaped from the former in a few minutes, but it will still be found in the latter. This may be easily ascertained by applying the flame of a candle to the mouth of each glass; the contents of the latter only will burn.

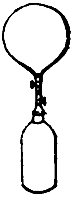

Fig. 4.

48. Hydrogen is *highly combustible, but does not support combustion.* In these respects hydrogen exhibits opposite properties to those of oxygen. 1. If a lighted taper be introduced into a jar of hydrogen, the gas burns with a pale blue flame, but the taper is extinguished. 2. The *philosophical candle* is a bottle furnished with a cork, into which a slender glass or metallic tube is fixed. The materials for generating hydrogen being introduced, and the cork fitted air-tight, a jet of hydrogen rises from the tube, and may be inflamed by a burning body, or the electric spark. In these cases, combustion takes place only where the hydrogen is in contact with the air, the oxygen of which is necessary to support the combustion. 3. If a portion of hydrogen be mixed with a sufficient quantity of atmospheric air to burn it completely, or with a quantity between two and three times its volume, combustion takes place immediately on

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48. What are the properties of hydrogen with reference to combustion? By what experiments may the combustibility of hydrogen be exhibited.

the application of flame, and is attended with *explosion*. 4. If, instead of atmospheric air, one volume of oxygen be mixed with two of hydrogen, the explosion is much more *violent*. The experiment may be easily performed by blowing soap-bubbles with the mixed gases, from a bladder, as already described, and igniting them as they ascend, or while they are still on the surface of the water. 5. The explosions may be so contrived as to produce a musical sound. If an open glass tube of about two feet in length be held over the jet arising from the *philosophical candle*, a succession of slight explosions is produced, as the gas rises and mixes with the air in the tube; and these follow each other so quickly as to produce a continuous sound or note. The mode of performing this experiment is shown in the adjoining figure.

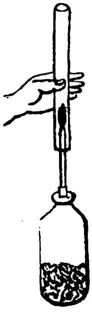

Fig. 5.

49. Hydrogen is *one of the most inflammable of bodies*. Its combustion is instantly effected by flame, by the electric spark, or by the approach of a red-hot body. But the combustion of hydrogen may be determined at much lower temperatures, by the action of metals which have no tendency to oxidize. The *action of spongy platinum upon hydrogen* is very remarkable in this respect: it produces explosion of a mixture of hydrogen and oxygen as rapidly as flame or the electric spark, provided the gases be pure and mixed in the exact proportions of two volumes to one. By this means Dobereiner contrived an apparatus by which instantaneous light may be produced. The figures *a* and *b* represent two glass vessels, the former of which is prolonged into a tube which reaches nearly to the bottom of the latter, and has a strip of zinc coiled round its lower extremity. The lower vessel is half filled with a mixture consisting of one part of sulphuric acid with five or six parts of water. The upper vessel is then fixed air-tight into its neck, by grinding or cement. Hydrogen gas is immediately disengaged in the lower vessel, and, by pressure upon the surface of the liquid, forces this into the upper vessel, the stopper of which, being conical, allows the air to escape. The lower vessel is by this means soon nearly filled with hydrogen. A brass tube is cemented to the neck *c*, and furnished with a stop-cock *d*;

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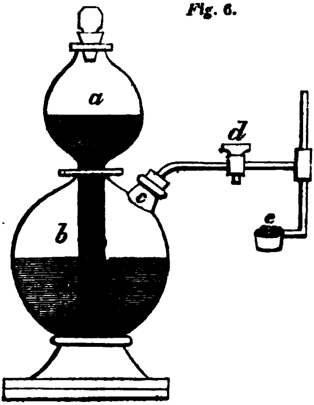
49. Explain the action of spongy platinum upon hydrogen.

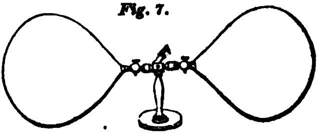
the box *e* contains some spongy platinum at the end of the tube. When it is required to produce light, the stop-cock is turned, and a jet of hydrogen is immediately thrown upon the platinum, which quickly becomes red-hot, and inflames the hydrogen, as it issues from the tube. As the hydrogen escapes, the acid again descends into the lower vessel, comes in contact with the zinc, and the process is renewed. This action of the platinum will take place in temperatures considerably below the freezing point.

Fig. 6.



50. *Uses of Hydrogen.*—The flame of hydrogen, though feebly luminous, is intensely hot. The most intense heat which can be produced, is caused by the combustion of hydrogen in oxygen gas. Upon this principle is constructed the *oxy-hydrogen blow-pipe*, the most important of the present applications of hydrogen gas. The simplest form of apparatus for this purpose consists in two bladders, the one filled with oxygen, the other with hydrogen, and both furnished with a blow-pipe tube and a stop-cock. The apparatus is shown in the figure above. A stream of hydrogen from one bladder is then directed upon the substance to be heated, and a stream of oxygen, from the other, is made to enter the flame just where it issues from the tube. The heat produced by the combustion of these mixed gases is

Fig. 7.



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50. Describe the oxy-hydrogen blow-pipe. Is hydrogen remarkable for yielding excessive heat, or excessive light?

applied to effect the fusion of the most refractory substances, and also to produce the most brilliant light by the ignition of small portions of lime. This light has been found sufficiently intense to serve for the illumination of solar microscopes, and for conveying signals to almost incredible distances.

51. *Water, or Protoxide of Hydrogen.*—The sole product of the combustion of hydrogen and oxygen, is *Water.* The composition of water may be proved *synthetically*, or by the *formation* of water by the combination of these two gases. The simplest way of illustrating the formation of water is to invert a dry glass vessel over the flame of the *philosophical candle* (p. 32); as the combustion proceeds, *dew* is copiously deposited on the sides of the vessel, owing to the combination of hydrogen with the oxygen of the air. The *formation* of water may be also shown by introducing the mixed gases into a strong thick vessel of glass *a*, furnished with a stopper *s*, which can be pressed tightly down by means of a screw, and with a stopcock *p*. By means of two wires, *w w*, which are inserted into the stopper, and communicate with the interior of the vessel, an electric spark is passed directly through the gases, which combine with explosion, and water is deposited upon the sides of the glass.

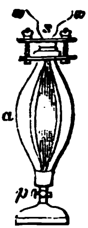

Fig. 8.

52. On the other hand, the composition of water may be proved *analytically*, or by *resolving water into its elements.* This is effected by means of the Galvanic battery. The adjoining figure represents a glass vessel, with a perforation on each side furnished with a cork, through which are passed wires connected with the two poles of a galvanic battery. The vessel is partly filled with water. Two glass tubes, A and B, both filled with water, are inverted in the vessel. As the stream of electricity passes from

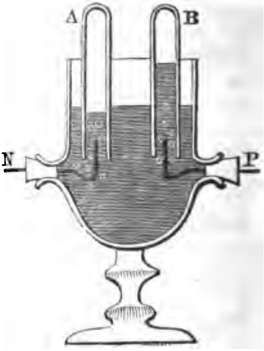

Fig. 9.

P to N, the water undergoes *decomposition*, the oxygen rises in one of the glass tubes, the hydrogen in the other, the volume of the latter being *twice* as great as that of the former. By this experiment, the proportions in which these elements combine, by *volume*, may be exactly determined: they are *two volumes of hydrogen, and one of oxygen.* The same result is obtained by *synthetic* experiment: if one volume of oxygen be mixed with three of hydrogen, and the mixture be exploded by the electric spark, one volume of hydrogen remains after the explosion; if the explosion be made with two volumes of oxygen and two of hydrogen, one volume of oxygen remains after the explosion. The proportions in which these gases combine by *weight*, is 1 of hydrogen to 8 of oxygen. It has been found, by careful experiments, that 100 parts of pure water consist of 11·1 of hydrogen and 88·9 of oxygen, which is the ratio of 1 to 8·009, or very nearly the proportion above stated.

53. *Experiments.*—(1.) Put about an ounce of iron filings into a phial, with about three or four ounces of water. Pour a little sulphuric acid upon the contents, and hydrogen gas will be evolved.

(2.) Procure a bladder furnished with a stop-cock, fill it with a mixture of hydrogen and oxygen gases, and adapt a tobacco-pipe to it. With this simple apparatus blow soap-bubbles, and apply to them a lighted match, when they will explode with a smart noise.

(3.) Put a little alcohol into a tea-cup, set it on fire, and invert a large bell-glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell, which, by means of a dry sponge may be collected, and its quantity ascertained. This may be adduced as an example of the formation of water by combustion.

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51. What is the chemical composition of water? How may the composition of water be proved synthetically?—52. Explain the composition of water analytically. What is the difference between synthesis and analysis? What are the proportions of the ingredients of water by volume, and by weight?

CHAPTER IV.

OF NITROGEN.

54. *General Remarks.*—Nitrogen, in its *elementary* state, is a *gas*. It is one of the very few elementary bodies which are found naturally in an uncombined state. The great bulk of this gas is confined to the *atmosphere*, of which it constitutes about four-fifths, or 80 per cent., the rest being principally oxygen. It forms a constituent element in animal and several vegetable substances, but enters very sparingly into natural mineral productions. It is remarkably distinguished from other elementary bodies by the *absence of active properties*. Notwithstanding the negative properties of nitrogen in its simple state, it forms most important and energetic compounds when made to combine with other substances; some of these are atmospheric air, aqua-fortis, ammonia, and prussic acid. The name *Nitrogen* was given to this gas from its being an element in nitric acid; from its being incapable of supporting respiration, it has been termed *Azote*, or life-depriver.

55. *Modes of procuring Nitrogen.*—Nitrogen is generally procured from atmospheric air, every 100 parts of which consist, by measure, of 79 of nitrogen and 21 of oxygen.

56. When the air exhaled from the lungs of an animal has been washed with lime-water, which removes the carbonic acid, the gas which remains is found to be incapable of supporting respiration. This is *impure* nitrogen gas.

57. If a bell-glass containing atmospheric air be inverted over a lighted taper, in a vessel containing a little water, as shown in the adjoining figure, the flame becomes gradually more dim, and is presently extinguished. The greater part of the oxygen of the air is consumed in supporting the combustion of the taper; the remaining gas is principally nitrogen. The effect is

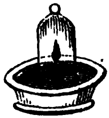

Fig. 10.

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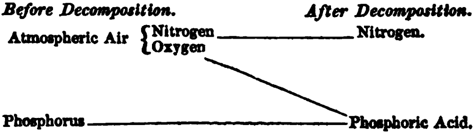
54. What is nitrogen? Is it found naturally in an uncombined state? In what proportion does it enter into the composition of atmospheric air? By what circumstance is this gas remarkably distinguished from other elementary bodies? What is the meaning of the term nitrogen? Why is this gas also termed azote?—55. How is nitrogen generally procured?—56. How may nitrogen be procured from the air exhaled from the lungs of animals?—57. Explain the process of procuring nitrogen by means of combustion.

rendered more striking, by the gradual rising of the water into the bell-glass, in proportion as the oxygen is consumed. If, instead of the taper, a paste made of iron filings and sulphur be placed under the bell-glass, on a stand raised above the water, the oxygen of the contained air will be gradually diminished, and the water will ascend proportionably. The residue is principally nitrogen, as in the former case.

58. If, instead of a lighted taper, a portion of phosphorus be burned under similar circumstances, the whole of the oxygen will be consumed by the combustion. In this experiment, the vessel becomes filled with white fumes, arising from the combination of the phosphorus with the oxygen of the air; this substance is phosphoric acid. If the experiment be performed in a receiver over water in a pneumatic trough, the fumes are absorbed by the water, which rises proportionably in the receiver; and nitrogen gas *alone* remains. These *changes* are shown in the following *diagram*:—



59. *Properties of Nitrogen.*—Pure nitrogen is a permanently elastic fluid, without colour, taste, or smell. It is a singularly *inert* element. It does not change the blue colour of vegetables. It is not a supporter of combustion; but, on the contrary, extinguishes the flame of any burning body immersed in it. It does not support respiration; an animal soon dies in it, not because it exerts any injurious action upon the system, but simply because *oxygen* gas is excluded. The principal use of nitrogen in the atmosphere appears to be that of *diluting* the oxygen, and thereby subduing the activity of combustion and other oxidating processes. Nitrogen is not inflammable, though it may be made, under certain circumstances, to combine with oxygen.

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58. Describe the changes which take place on the combustion of phosphorus in atmospheric air.—59. What are the general properties of nitrogen? What is its principal use in the composition of atmospheric air.

It is sparingly absorbed by water: this liquid, when deprived of air by ebullition, takes up about one and a half per cent. of the gas.

60. *Analysis of Atmospheric Air.*—The general properties of Atmospheric Air have been explained in the preceding volumes of this series. It is necessary here also to point out the various modes of *analysis* which are practised in order to ascertain the quantity of nitrogen or of oxygen contained in the atmosphere. This inquiry constitutes the subject of *Eudiometry*, a term which denotes the *measuring of the quality* of the atmosphere. For this purpose substances are employed which will absorb or consume all the oxygen of a confined portion of air, care being taken to employ a substance which will not mix with, or alter, the volume of the nitrogen.

61. In *Achard's Eudiometer*, this effect is produced by the slow combustion of *phosphorus*. A graduated glass tube *a b* is blown at one end into a bulb *c*, into which small pieces of phosphorus are introduced, in the proportion of one-third of a grain of phosphorus to one cubic inch of atmospheric air; the remainder of the tube is filled with mercury, and its open extremity is immersed in a jar filled with the same metal. The oxidation of the phosphorus is increased by heating the bulb by the flame of a candle. The oxygen of the atmospheric air in the tube unites with the phosphorus, leaving a residue of nitrogen; by comparing this with the volume of atmospheric air employed in the experiment, the relative quantities of the constituent gases are determined; the comparison always indicates 20 or 21 per cent. of oxygen.

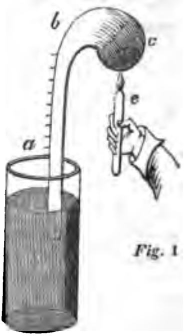

Fig. 1

62. In *Volta's Eudiometer*, the effect is produced by the combination of one volume of oxygen with two volumes of hydrogen, to form water. This instrument consists of a

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60. What is meant by Eudiometry? By what means is the quality of the atmosphere determined?—61. Explain the principle of Achard's eudiometer.—62. Explain the use of Volta's eudiometer.

strong graduated glass tube *a b*, closed at its extremity *a*, and open at *b;* two wires *c d* are fixed into its sides, for the purpose of passing an electric spark through the contents of the tube. A portion of atmospheric air is carefully measured in a graduated tube, and mixed with a quantity of hydrogen gas, which is rather more than sufficient for combining with all the oxygen present. The mixture is introduced into the eudiometer, and an electric spark passed through it, the open extremity being closed by the thumb at the moment of detonation, in order to prevent any of the mixture from escaping. Water is formed by the combination of one volume of oxygen with two of hydrogen; one third, therefore, of the diminution of the mixed gases represents the volume of oxygen in the atmospheric air employed.

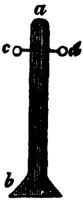

Fig. 12.

63. *Compounds of Nitrogen and Oxygen.*—The compounds of Nitrogen and Oxygen are five; of these, two are oxides, and three acids. They afford striking instances of the direct proportions in which gases combine with each other by *volume.* Their composition and equivalents, as stated by Turner, are as follow:—

	By Volume.		*By Weight.*		
	Nitr.	Oxyg.	Nitr.	Oxyg.	Equiv.
Nitrous oxide . .	100 .	50	14·15 +	8 =	22·15
Nitric oxide . .	100 .	100	14·15 +	16 =	30·15
Hyponitrous acid .	100 .	150	14·15 +	24 =	38·15
Nitrous acid . .	100 .	200	14·15 +	32 =	46·15
Nitric acid . . .	100 .	250	14·15 +	40 =	54·15

64. *Nitrous Oxide.*—Nitrous oxide is a colourless gas, with a sweet taste, and a faint agreeable odour. It is a supporter of combustion: a candle burns in it with less brilliancy than in oxygen, but with greater than in common air. With an equal bulk of hydrogen, it forms a mixture which explodes violently by flame or the electric spark; the hydrogen combines with the oxygen, and nitrogen is liberated. The most remarkable property of this gas is its effect on animal life, when breathed. Davy discovered that it supports respiration for a few minutes. He thus de-

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63. What are the compounds of nitrogen and oxygen? State in what proportions these gases unite with each other by volume.—64. What is nitrous oxide? What is the most remarkable property of this gas?

scribed the effects produced on himself by inhaling this gas. 'Having previously closed my nostrils, and exhausted my lungs, I breathed four quarts of nitrous oxide from and into a silk bag. The first feelings were those of giddiness; but in less than half a minute, the respiration being continued, they diminished gradually, and were succeeded by a sensation analogous to gentle pressure on all the muscles, attended by a highly pleasurable thrilling, particularly in the chest and the extremities. The objects around me became dazzling, and my hearing more acute. Towards the last inspiration the thrilling increased, the sense of muscular power became greater, and at last an irresistible propensity to action was indulged in. I recollect but indistinctly what followed: I know that my motions were various and violent. These effects very soon ceased after respiration. In ten minutes I had recovered my natural state of mind. The thrilling in the extremities continued longer than the other sensations. The gas has been breathed by a very great number of persons, and almost every one has observed the same things. On some few, indeed, it has no effect whatever, and on others the effects are always painful.' Davy breathed nine quarts of this gas for three minutes; and twelve quarts for rather more than four minutes, but was unable to continue the experiment for a longer period.

65. *Nitric Acid.*—This is one of the most important of the acids. It cannot be procured in a separate state, but always occurs in combination. The most simple form in which it is procured is in solution with water, and it is commonly known by the name of *aqua fortis*. It enters into the composition of *nitre* or *saltpetre*, which is a nitrate of potash. Nitric acid is exceedingly *corrosive*, and acts with great energy on substances which are disposed to combine with oxygen; hence, it is much employed as an *oxidizing agent*. Nearly all the metals are oxidized by it; and some of them, as mercury, copper, zinc, and tin, with great violence. When poured upon burning charcoal, the brilliancy of the combustion is considerably increased. Sulphur, phosphorus, and iodine, are converted into acids by its action. When mixed with a fourth of its bulk of oil of vitriol and thrown upon a few drops of oil of turpentine, an explosive

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65. In what state does nitric acid always occur? Why is it employed as an oxidizing agent? What is its action on vegetable substances?

combustion of the oil takes place. All vegetable substances are decomposed by it: its oxygen combines with the hydrogen and carbon of these substances, forming water with the one, and carbonic acid with the other. Animal substances are also decomposed by nitric acid; it stains the skin and nails of a yellow colour, and acts upon the former as a powerful cautery. The orange patterns upon woollen table covers are produced by this agent. The strongest nitric acid, however, produces no violent action upon certain organic substances, as woody fibre and starch, for a short time, but combines with them and forms remarkable compounds.

66. *Experiments.*—(1.) Take a few iron filings, mix them with a little sulphur, and moisten the mass with water. Put this mixture into a large glass jar, and cork it close. In a few days the oxygen will be absorbed by the mixture from the air which was previously in the glass, and the residue will be found to be *nitrogen gas.*

(2.) Take three measures of oxygen gas and one measure and a quarter of nitrogen gas, and pass a number of electric explosions through the mixture. This will occasion a union of these gases, and *nitric acid* will be the product.

(3.) Pour some sulphuric acid upon an ounce or two of nitrate of potash in a glass retort; apply heat by means of a lamp, and *nitric acid* may be collected.

(4.) Pour some concentrated nitric acid upon pieces of iron, and very little action will take place; but, if a few drops of water be added, violent effervescence will immediately commence, and the acid will be rapidly decomposed, clouds of red *nitrous gas* will be evolved in abundance, and the metal will be perfectly dissolved.

(5.) Pour upon a few filings of copper a little diluted nitrous acid, in the proportion of about three parts of water to one of acid, and *nitric oxide gas* will be evolved.

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66. Explain the process of procuring nitrogen gas from iron filings, sulphur, and water. How may nitric acid be procured from oxygen and nitrogen gases? How may nitrous gas be formed from nitric acid, iron, and water? How may nitric oxide gas be obtained?

CHAPTER V.

OF CARBON.

67. *General Remarks.*—Carbon is a substance which occurs under a variety of forms. By chemists, the term is employed to denote the pure matter of *charcoal.* In its crystallized and pure state, it constitutes the *diamond*—the hardest and most brilliant body in nature. It enters very largely into the composition of vegetable substances, of which it may be considered, more perhaps than any other principle, the fundamental element. It is found abundantly in animal bodies, in which its effects are considerably modified by the presence of nitrogen. It occurs also in great quantities in the mineral kingdom, in which, in a nearly pure state, it forms the basis of *coal.* But it is found in still greater proportion in combination with oxygen, in the form of *carbonic acid*, which, combined with lime, constitutes *chalk* and *limestone*, two of the most abundant minerals in nature. A small portion of it, in the form of carbonic acid, enters into the composition of atmospheric air. Carbon, in its elementary state, is an *inert* substance; but with oxygen and hydrogen, it forms gaseous compounds of great energy, and of most deleterious properties.

68. *Diamond.*—Lavoisier first proved the diamond to contain carbon, by concentrating the sun's rays upon it, by means of a powerful lens, in a vessel of oxygen gas; the diamond was entirely consumed, oxygen disappeared, and carbonic acid was formed. It has been since proved, by numerous experiments, that the diamond is pure carbon, that charcoal is an oxide of carbon, and that the product of the combustion of the diamond is identical with that derived from different kinds of charcoal. In close vessels, the diamond undergoes no change from the most intense heat; but, when heated to redness in the open air, to about the melting point of silver, it is entirely consumed. The diamond affords an instance of the intrinsic worthlessness of an

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67. In what forms does carbon occur in nature? In what condition does it occur in combination with oxygen? In what state is carbon inert. and in what combination does it exhibit energetic properties?—68. How may the composition of the diamond be proved?

object upon which the highest value is set. The celebrated Regent Diamond, originally purchased by Mr. Pitt for £20,400, and afterwards placed in the hilt of Napoleon's sword, is now said to be valued at £260,000. Yet this precious gem is a mere piece of carbon, of somewhat more than an ounce in weight, and which may be resolved under the solar ray into a noxious vapour.

69. *Wood Charcoal.*—This variety of charcoal is the substance which remains when wood has been exposed to a red heat in closed vessels, and its gaseous and other volatile matters have been by this means expelled. Wood, when thoroughly dried at 212°, loses 57 per cent. of its weight; when dried at 304°, it loses 67 per cent.; the remaining 33 parts of baked wood yield, when calcined, 25 of charcoal, while 100 parts of the same wood calcined, without having been previously dried, leave only 14 per cent. of charcoal. The greater intensity of heat produced by burning charcoal than by wood, is owing to the abstraction of this large quantity of water. Owing to its porous nature, charcoal possesses the property of absorbing many times its volume of many of the gases at common temperatures, and of giving them out again unaltered when heated. Charcoal absorbs also odoriferous effluvia, arising from animal and vegetable matters; hence, it acts as an *antiseptic* agent, and removes the taint of meat which is undergoing putrefaction; the impurities of water are also removed by filtering it through charcoal. It is a common practice to char the inside of water, and of wine, casks; water is thus preserved from putridity, and the quality of wine improved. In the form of coarse powder, wood charcoal is employed as a filter for spirits, which are deprived by this means of their essential oil. Charcoal is highly combustible; when strongly heated in the open air, it becomes ignited, and burns away slowly without flame or smoke; in oxygen gas, its combustion is brilliant, and accompanied with the emission of sparks; the product of its combustion is carbonic acid gas. Charcoal is a very slow conductor of heat, but a good conductor of electricity.

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69. How is charcoal procured from wood? How is the intensity of the heat produced by burning charcoal proved to be greater than that obtained from wood? How does charcoal act as an antiseptic agent? What is the product of the combustion of charcoal in oxygen gas?

70. *Animal Charcoal.*—Animal charcoal, bone-charcoal, ivory-black, and bone-black, are names applied to an impure charcoal procured from bones heated to redness in close vessels; the residue is a black mass, consisting of charcoal mixed with the earthy matters of bone. Animal charcoal, reduced to a fine powder, absorbs the colouring principles of most animal and vegetable substances, and is extensively used for decolorizing syrup, and for purifying many organic liquors. A similar property is possessed by charcoal prepared by calcining dried blood, horns, hoofs, or clippings of hides, in contact with carbonate of potash, and washing the calcined mass with water. Charcoal loses the property of absorbing colouring matters by use, but recovers it by being heated to redness. Ivory-black is the most feeble decolorating variety procured from animal matters, but is still much superior to the best charcoal procured from wood.

COMPOUNDS OF CARBON WITH OXYGEN.

71. Carbon surpasses all bodies in its affinity for oxygen at a high temperature. These elements combine, and form an *acid* and an *oxide*, in the following proportions of each:—

	Carbon.	Oxygen.	Equiv.
Carbonic oxide .	6·12 or 1 equiv. +	8 or 1 equiv. =	14·12
Carbonic acid .	6·12 or 1 equiv. +	16 or 2 equiv. =	22·12

72. *Carbonic Acid.*—Carbonic acid was first described by Dr. Black under the name of *fixed air*. He discovered it in limestone and magnesia, and found that it could be separated from these substances by heat or the action of acids. He also observed, that the same gas is formed during respiration, fermentation, and combustion. The air of an ordinary expiration contains on an average, 3·45 per cent. of carbonic acid, and the proportion varies from 3·3 to 4·1 per cent., being greatest at noon, and least during the night. Carbonic acid is also a product of the vinous fermentation, imparting an agreeable pungency to fermented liquors, which

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70. What is animal charcoal? For what purposes is it employed?—71. What are the compounds of carbon and oxygen? In what proportions do these elements combine in the formation of carbonic acid and of carbonic oxide, respectively?—72. Under what name was carbonic acid first described; and why so? What amount of this gas is contained in the air of an ordinary expiration? What chemical operations are attended by the evolution of carbonic acid gas? In what state does it occur in the composition of rocks? What is the amount of this gas in atmospheric air? What in sea-water?

become *stale* when deprived of it by exposure to the air. The combustion of carbonaceous fuel is attended with the production of vast quantities of this gas. Carbonic acid is also contained in the earth, and is discharged from volcanoes and fissures in their neighbourhood. It issues directly from the earth in the *Grotto del Cane* in Italy, and at Pyrmont in Westphalia. This gas accumulates at the bottom of wells, forming a noxious and fatal atmosphere, called by miners *choke damp*. Many mineral springs, as those of Tunbridge, Pyrmont, and Carlsbad, are strongly charged with carbonic acid. In combination with lime, it forms extensive masses of rocks, occurring in all countries, and in every geological formation. It is always present, though in a small quantity, in the atmosphere, at every elevation above the level of the sea. The atmosphere contains only a thousandth part of its weight of carbonic acid; and yet, small as this proportion appears, it is quite sufficient to supply the whole of the present generation of living beings with carbon for a thousand years, even if it were not renewed. Sea-water contains $\frac{1}{12400}$th of its weight of carbonate of lime; and this quantity, although scarcely appreciable in a pound, is the source from which myriads of marine mollusca and corals are supplied with materials for their habitations. Carbonic acid is also a product of many natural operations, as of the germination and vegetation of plants. From these and other sources, carbonic acid is continually forming around us in vast quantities; but by some compensating means it disappears as fast as it is formed; and the atmosphere, which, without this adjustment, would soon become impregnated with carbonic acid to a fatal extent, barely contains traces of it.

73. *Mode of procuring Carbonic Acid.*—There are several ways of procuring carbonic acid. 1. If charcoal be burned in oxygen gas, intense heat and light are produced, the carbon unites with the oxygen, and carbonic acid gas is formed. In the combustion of pure carbon, as of the diamond, the oxygen undergoes no change of volume: carbonic acid gas contains, therefore, its own volume of oxygen.—2. A more convenient mode of procuring the acid is to pour upon some carbonate of lime, as common *limestone*, *marble*,

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73. How may carbonic acid gas be procured from charcoal? How may it be obtained from marble?

or *chalk*, an acid which has a greater affinity for the lime than the carbonic acid possesses. Hydrochloric acid, diluted with two or three times its weight of water, takes the lime from the carbonic acid, which escapes with effervescence, and may be collected by means of the pneumatic trough, in the manner already described (p. 24). The gas cannot be long retained over water, owing to its solubility in this liquid; it should, therefore, be collected over mercury.

74. *Properties of Carbonic Acid.*—Carbonic Acid is an elastic *gas* without colour or scent. Water and other liquids may be charged with a great quantity of this gas by mechanical pressure; the quantity of the gas absorbed is in exact proportion to the compressing force; water absorbs twice its volume when the pressure is doubled, and three times its volume when the pressure is trebled. On removing the pressure, as when a bottle containing any aerated liquid is uncorked, the carbonic acid gas escapes with effervescence. It is to the presence of this gas that the agreeable acidulous taste of ginger beer, champagne, soda, and other aerated waters, is owing. Water, when fully saturated with this gas, sparkles as it is poured from one vessel into another. The solution communicates to litmus paper a red stain, which disappears on exposure to the air. On adding lime-water to the solution, a cloudy precipitate is formed, which is again dissolved by the carbonic acid; but on adding lime-water, till the whole of the free acid is neutralized, a permanent precipitate is formed of carbonate of lime. The whole of the carbonic acid in a solution of water is expelled by boiling. Boiled water becomes insipid, owing to the absence of the carbonic acid and other gases, which had been absorbed by it from the atmosphere.

75. Carbonic acid *does not support combustion:* it extinguishes the flame of all burning bodies. A lighted taper, introduced into a jar of this gas, is immediately extinguished. The gas is so heavy, that it may be poured, like a liquid, upon a lighted taper, with the same effect of extinguishing it. The check upon combustion, produced by carbonic acid, is not owing to the mere absence of oxygen; for a candle will not burn in a mixture of four measures of atmospheric

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74. What are the general properties of carbonic acid gas? How are aerated waters prepared? What is the reason of the insipidity of water which has been boiled?—75. Is carbonic acid a supporter of combustion? How may it be proved that it is a heavy gas? Is it combustible or incombustible?

air and one of carbonic acid. Carbonic acid is *incombustible*, and cannot be made to unite with an additional portion of oxygen. It is a compound, therefore, in which carbon is in its highest degree of oxidation.

76. Carbonic acid is *irrespirable:* it is fatal to animal life, when inspired. No animal can live in an atmosphere which contains sufficient carbonic acid to extinguish a lighted candle; hence, it is a usual practice to lower a burning taper into a well or pit, before descending into it; if the taper continue to burn, no danger is apprehended. In the *Grotto del Cane*, the gas exhaled from the ground occupies the lowest stratum of about 18 inches, while the upper portions of the air are pure; for the instruction of strangers, a dog and a man are introduced into the cave; the dog dies, the man is unaffected. But the incautious inhalation of the vapours of charcoal in close apártments, and in the large vessels of breweries and distilleries, has afforded numerous examples of the fatal effects of carbonic acid upon man. It acts upon the animal system like a narcotic poison. Carbonic acid may exist in the atmosphere in sufficient quantity to produce insensibility, without being sufficient to extinguish flame.

77. The presence of carbonic acid is *tested* by means of *lime-water*. The lime combines with the acid, forming carbonate of lime, which renders the solution turbid, and forms a white flaky precipitate. Lime-water is frequently employed to remove carbonic acid from gaseous mixtures which contain it.

78. Carbonic acid gas has been condensed into a limpid colourless *liquid*, under a pressure of thirty-six atmospheres at 32° F. Thilorier lately discovered that at—148° F., carbonic acid becomes *solid*, and remains in this condition for some minutes, even when exposed to the air, without compression. Its elasticity, which in a liquid state is so great as to produce an explosion equal to that of the same weight of gunpowder, is destroyed by solidification, and the new solid is gradually dissipated by evaporation. Another curious fact is, that this gas is *solidified by* its sud-

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76. What is the effect of carbonic acid on respiration? Explain the phenomena which occur on entering the Grotto del Cane? What is the effect of this gas on the animal system?—77. How may the pressure of carbonic acid be tested?—78. Under what circumstances can this gas be reduced to the solid state?

denly passing from the liquid to the gaseous state; the near approach of its molecules, which renders it solid, being caused by the expansion of a liquid which occupies instantaneously a space four hundred times greater than its original volume. If a jet of liquid carbonic acid be directed into a small glass vial, this becomes rapidly and almost entirely filled with a white flocculent powdery substance, which adheres so strongly to the glass that it cannot be removed without breaking the bottle. A fragment of solid carbonic acid, slightly touched by the finger, glides rapidly over a polished surface, as if it were raised by the gaseous atmosphere which constantly surrounds it, until it entirely disappears. If a small quantity of this substance be introduced into a small flask, hermetically stopped, the interior becomes filled with a thick vapour, and the stopper is violently expelled. Solid carbonic acid is completely evaporated, and only rarely a slight humidity remains, which must be attributed to the action of the air on a very cold body, of which the temperature is below that at which mercury freezes. Its abundance, and the promptitude with which it is produced in cavities, where neither air nor watery vapour, held in it, can penetrate, are characters which cannot be mistaken.

79. *Woolfe's Apparatus.*—It is sometimes desirable to impregnate water, for medicinal purposes, with carbonic acid. A saturated solution of this gas may be made by transmitting a stream of it through a vessel of cold water during the space of half an hour. This operation may be conveniently performed by means of what is called *Woolfe's Apparatus.* This, in its simplest form, consists of three bottles, mounted, with tubes, as represented in the figure, in a mahogany tray. The bottles are half filled with water. The vapour from a receiver or a retort is conveyed into the first bottle; that portion of it which is not condensed in the water of this bottle, passes on by the bent tube

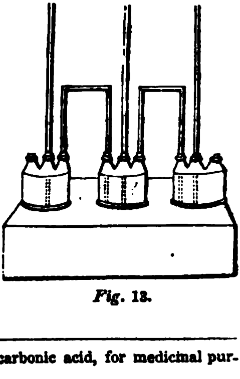

Fig. 13.

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79. How may water be impregnated with carbonic acid, for medicinal purposes? Describe Woolfe's Apparatus.

into the second; and from this, if required, into the third; the portion of gas which is not absorbed by the last, is conveyed by a curved tube into an inverted jar placed in a pneumatic trough, as in the figure on the title-page. Besides the bent tube, each bottle is provided with a *safety tube*, the lower extremity of which opens beneath the surface of the water, while the upper communicates with the atmosphere. The object of this tube is to prevent the fluid being forced backward into the receiver or retort by pressure of the atmosphere, in cases of sudden absorption; for it frequently happens in chemical processes, from the irregularity of the heat, or other circumstances, that the condensation is more rapid in proportion to the supply of vapour at some period of the operation than at others. In such cases, air is supplied by means of the safety tube.

80. Instead of this apparatus, a curved *Welter's tube* is now generally employed, as more convenient. In the figure on the title-page, which presents a useful modification of this apparatus, *a* is the receiver placed on a wreath of straw; *c*, *d*, two of Woolfe's bottles; *g* a jar inverted in a mercurial trough *f*. Each bottle is furnished with a Welter's tube. Into these tubes water is poured, till the balls *b*, *e*, are half full. When absorption takes place, the water rises in the ball till none remains in the tube, and then the air rushes in. On the other hand, no gas can escape, as it has to overcome the pressure of a high column of water in the perpendicular tube. In this apparatus, the vapour is condensed in the receiver, and the gas passes on into the two bottles; the portion of gas which is not absorbed by water, or condensed at its exit from the last bottle, is conveyed into the jar standing in the mercurial trough.

81. *Carbonic Oxide.*—It has been stated that carbonic acid gas consists of two equivalents of oxygen and one of carbon. If a stream of this gas be transmitted over fragments of red-hot charcoal contained in an iron or porcelain tube, one equivalent of the oxygen is liberated, and the remainder is a compound of one equivalent of oxygen and one of carbon. This is *carbonic oxide*. It may be procured by various other substances, which deprive carbonic acid, at

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80. Describe the apparatus represented in the figure on the title-page?—81. How may carbonic oxide be procured? When chalk and iron filings are mixed together and exposed to a red heat, what chemical changes take place?

is deprived of half of its oxygen. Thus, if two parts of well-dried chalk, a compound of carbonic acid and lime, and one of pure iron filings, be mixed together, and exposed in a gun-barrel to a red heat, a quantity of gaseous matter is evolved, which may be collected over water. This matter consists of carbonic acid and carbonic oxide; by washing the mixed gases with lime-water, the acid is absorbed, and the oxide is left in a state of purity. In this operation, the carbonic acid of the chalk is converted into carbonic oxide by yielding oxygen to the iron filings, which thus become an oxide of iron.

82. *Properties of Carbonic Acid.*—Carbonic oxide is a *colorless gas.* It possesses no acid properties; nor does it combine, like carbonic acid, with the alkalies. It is not more soluble in water than atmospheric air, nor has it ever been liquefied. Carbonic oxide is inflammable; it is inflamed by a lighted taper, though the flame of a taper immersed in it is extinguished; the product of its combustion is carbonic acid. A mixture of carbonic oxide and oxygen gases may be made to explode by flame, by a red-hot solid body, or by the electric spark. Carbonic oxide is irrespirable: when inspired, it acts on the system as a poison. Mr. Witter states that, on making three or four hearty inspirations of this gas, after having exhausted the lungs of common air as much as possible, the effect was an inconceivably sudden deprivation of sense and volition; he fell motionless on the floor.

83. *Experiments.*—(1.) If the diamond, supported in a perforated cup, be fixed at the end of a jet, so that a stream of hydrogen can be thrown on it, it is easy, by inflaming the jet, to ignite the gem, and whilst in that state to introduce it into a globe or flask containing oxygen. On turning off the hydrogen, the diamond enters into combustion, and will go on burning till nearly consumed. The loss of weight, and corresponding production of carbonic acid, are thus beautifully shown. The experiment is intended to prove that the diamond is capable of supporting its own combustion in oxygen, without the continued application of extraneous heat.

(2.) Put into a pint jug a very little water, about half an ounce of sulphuric acid, and a little chalk, or powdered marble—carbonic acid gas will be produced. If, when the effervescence has ceased, the gas be cautiously poured into a tall jar, containing a small

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82. What are the properties of carbonic oxide?

lighted taper, the taper will be as effectually extinguished, as if water had been employed.

(3.) Make a little charcoal perfectly dry, pulverize it very fine, and put it into a warm tea-cup. If some strong nitrous acid be now poured in, so as to trickle down the inner side of the vessel, and mix with the charcoal, it will burn rapidly, giving out a beautiful flame, and throwing up the powder so as to resemble a brilliant firework.

(4.) Let a receiver be filled with oxygen gas, and inverted in a shallow pan of water. To the stopper of the receiver suspend by a wire a piece of charcoal, which has been previously ignited, and immerse it quickly into the gas. The charcoal will burn with brilliant coruscations. When the combustion is over, the oxygen gas will be found to have been consumed, and the water to be impregnated with carbonic acid gas; and if some transparent lime-water be poured in, the whole of the liquid will become opaque from the carbonate of lime now formed.

CHAPTER VI.

OF SULPHUR.

84. *General Remarks.*—Sulphur is one of the few substances which exist naturally in an elementary state. It occurs in great quantities in the mineral kingdom; it is exhaled from volcanoes in a pure state, or in combination with hydrogen, in which state it forms a very deleterious gaseous compound, called *sulphureted hydrogen;* it condenses in fissures in the neighbourhood of volcanoes, and is there found in a massive state, constituting *sulphur veins*, from which the principal part of the sulphur of commerce is obtained. Sulphur is found in great abundance in combination with several metals, as iron, lead, copper, silver, antimony, and zinc; and it may be procured in large quantities, by exposing the iron ore, called *iron pyrites*, to a red heat in close vessels. Sulphur is also found, in a greater or

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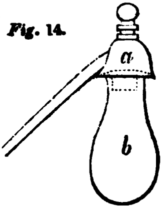
84. In what forms does sulphur occur in nature? From what source is the sulphur of commerce principally obtained?

less proportion, in most animal, and in many vegetable, products; a small quantity is always found associated with albumen, in the liquid state in the egg, in the solid state in the hair.

85. *Preparation of Sulphur.*—In order to obtain sulphur in a pure state, it must be *sublimed* (p. 20) in a vessel called an *alembic*. This apparatus consists of a body *b*, to which is fitted a head *a* of a conical shape, having its base depressed lower than the neck of the body, so that the vapours which rise, and condense upon its sides, run down into the circular channel formed by its depressed part, and are thence conveyed by the nose or beak into a receiver. The sulphur is put into the lower part *b*. The alembic is then placed in a vessel of sand, called a ***sand-bath***, and this is heated by a furnace. By means of the sand-bath, the sulphur is fused more gradually and equably, than by placing it directly over a fire. When sufficiently heated, the sulphur rises in the form of a thick, white vapour, and condenses on the sides of the head in the form of a fine yellow crystalline powder, commonly called *flowers of sulphur;* from the minuteness of its particles it is sometimes called *flour* of sulphur. On washing this substance several times with water, pure sulphur is obtained.

Fig. 14.



86. *Properties of Sulphur.*—Sulphur, in its simple state, is a solid body, of a yellow colour, without taste or smell, but emitting a peculiar odour when rubbed. It is remarkably brittle: a roll of it, held in the hand, frequently breaks with a crackling sound. It is a non-conductor of electricity, and is excited negatively by friction. It fuses at 226°, and between this temperature and 280° it forms a clear liquid of an amber colour. When melted and thrown into cylindrical moulds, it forms the ***roll sulphur*** of commerce. At near 320° it begins to thicken, and acquires a reddish tint; and, between 428° and 482°, it becomes so thick that the containing vessel may be inverted without the sulphur

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85. How is sulphur prepared? What is an alembic? What is meant by *flowers of sulphur?*—86. What are the general properties of sulphur? What are the peculiar effects of different degrees of heat upon sulphur? What is *roll sulphur?*

running out. From 482° to its boiling point, it again becomes liquid, though not to the same extent as at 248°. When heated to 428°, and poured into cold water, it acquires the consistency of softened sealing-wax, and is used for taking impressions from seals. Sulphur is exceedingly volatile; it begins to evaporate before it is completely fused. At about 600°, it volatizes rapidly, and its vapour condenses in close vessels in the form of the crystalline *flowers of sulphur*, above described.

87. Sulphur is *inflammable*. When heated in the open air to 300°, it is inflamed, and burns with a pale-blue light. In oxygen gas, its combustion is much more vivid, and its flame is of a much lighter colour. Even at 190° it burns, but its combustion is so feeble that the quantity existing in gunpowder may be all consumed without explosion; this may be effected by spreading out the gunpowder on a hot tile. In these cases, the sulphur combines with oxygen, and emits copious fumes, consisting of *sulphurous acid*, a substance possessing remarkable bleaching properties. Owing to its power of exhausting the oxygen of a confined portion of air by its combustion, and to the negative influence which sulphurous acid exerts upon the combustion of other bodies, sulphur is sometimes employed to extinguish combustion, as when a handful of lump sulphur is dropped into a burning chimney for the purpose of extinguishing the combustion.

88. *Sulphuric Acid.*—This important compound, frequently called *oil of vitriol*, consists of 1 equiv. of sulphur and 3 of oxygen. It is prepared by burning sulphur, previously mixed with other materials, in close chambers made of sheet lead. The subjoined figure, presents one of the most approved forms of the apparatus employed for this purpose, and affords an interesting illustration of chemical operation upon a large scale. In this figure, *a* represents a water boiler, with its furnace for supplying the chamber with steam; *b* is a section of a small furnace, called the burner, upon the floor of which the sulphur burns, and in

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87. At what temperature does sulphur exhibit the phenomena of combustion? Prove that its combustion is feeble. What is sulphurous acid. Upon what principles is sulphur sometimes employed to extinguish combustion?—88. What is the composition of sulphuric acid? Explain the process of preparing sulphuric acid on the large scale. By what name is sulphuric acid known in commerce?

which there is a tripod, supporting an iron capsule, containing the materials for nitric acid, viz. oil of vitriol, and nitre or nitrate of soda. As the sulphur burns, it forms sulphurous acid vapours; and the heat of the burning sulphur separates nitric acid from the materials in the capsule; the two acids are thus mixed together, and are carried forward by the tube represented in the figure into the leaden chamber, where they meet with the steam also introduced near the same place from the water boiler. The nitric acid yields oxygen to the sulphurous acid; the former, consequently, passes into a lower state of oxidation, while the latter passes into a higher state; in other words, the nitric acid becomes peroxide of nitrogen, while the sulphurous acid becomes sulphuric acid. The leaden chamber is 72 feet in length by 14 in breadth and 10 in height, and is divided into compartments by leaden partitions placed across it, two of which, *d* and *f*, are suspended from the roof, and reach to within six inches of the floor, while the centre one *e* is fixed in the floor, and rises to within six inches of the roof. The gases which are uncondensed in the process pass off by a conduit tube *g*, which communicates with a tall chimney. The partitions serve to detain the vapours, and regulate their passage through the chamber, so that the sulphuric acid may be deposited before the vapours reach the conduit tube. A continuous current of air is transmitted through the chamber, in order to support the combustion uninterruptedly. The introduction of the steam supersedes the necessity of covering the floor with water previously to commencing the process. The acid thus prepared, is further concentrated in open leaden pans, till it begins to act upon the metal, and afterwards in retorts of platinum or glass. It still retains small quantities of nitrous acid and sulphate of lead, which may be removed by dilution with water and a second distillation. The acid is then in its most concentrated state, and consists of one atom of acid and one of water, the latter of which cannot be separated by heat. This is the *oil of vitriol* of commerce.

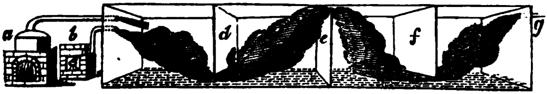

Fig. 15.

89. *Properties of Sulphuric Acid.*—The concentrated *Oil of Vitriol*, as prepared by the above process, is a dense, colourless, oily liquid, which boils at 620°, and freezes at —29°. It is one of the strongest of acids, and separates almost all others from their combinations. In its undiluted state, it is highly corrosive. It decomposes most organic substances, by the aid of heat, causing deposition of charcoal and formation of water. It has a strong sour taste, and reddens litmus paper even when greatly diluted. In its concentrated state, it dissolves small quantities of sulphur, and acquires a blue, green, or brown tint. Charcoal is also soluble in it to a small extent, communicating to it at first a pink, and afterwards a dark reddish-brown tint. It has a great affinity for water, with which it combines with the production of intense heat. In consequence of its affinity for water, it causes the liquefaction of snow, and, if mixed with it in certain proportions, produces intense cold. It absorbs watery vapour with avidity from the air, and is for this reason employed for freezing water by its own evaporation. The presence of sulphuric acid in a liquid may always be detected by means of *chloride of barium;* a white precipitate is formed, called sulphate of baryta, which is insoluble in acids and in alkalies. Sulphuric acid combines with bases, forming salts which are called *sulphates.*

90. *Experiments.*—(1.) If six grains of chlorate of potash, and three grains of sulphur, be rubbed together in a mortar, detonation will be produced, accompanied with vivid flashes of light. If these substances be mixed together in the proportion of ten grains of the former to three or four of the latter, and a little of the mixture be dropped into a wine-glass containing sulphuric acid, a beautiful column of flame will be perceived at the moment of contact.

(2.) Three parts of nitre, two of potash, and one of sulphur, mixed together by rubbing in a warm mortar, constitute a fulminating powder. If a little of this mixture be placed upon a fire-shovel over a hot fire, it gradually becomes black, and at last melts, and at that instant explodes with a violent report. This mixture is not dangerous, like the metallic fulminating powders.

(3.) The sulphurets decompose metallic oxides. Dissolve some sulphuret of potash in alcohol, and immerse a slip of white silk in the solution. If a drop of an aqueous solution of sulphate of man-

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89. What are the properties of sulphuric acid? What results may be obtained from its affinity for water? How may its presence in a liquid be detected? What is the product of the application of the test? What are the salts of sulphuric acid termed?

ganese be now applied, fibres of metallic manganese, bright as silver, will instantly appear.

(4.) Pour a little sulphuric acid upon a small quantity of quicksilver in a glass retort; apply heat, and sulphurous acid gas may be collected.

CHAPTER VII.

OF PHOSPHORUS.

91. *General Remarks.*—Phosphorus is a pale amber-coloured substance, resembling wax in appearance. Its name is derived from φῶς, *phos*, light, and φέρειν, *pherein*, to carry, from its inflammable property. Phosphorus does not exist in an elementary state, but is obtained by elaborate processes from various products. It exists in the mineral kingdom, in certain districts; it is also found in most plants. Phosphorus appears to be the connecting medium, which unites organization with the mineral constituent; for in combination with lime, it constitutes *bone-earth*, or the solid basis of bone; whereas, when phosphorus is absent, as in shells, and in other deposits of carbonate of lime, this substance seems to form no part of the living system.

92. *Preparation of Phosphorus.*—Phosphorus is prepared by heating bones to whiteness, by which means their animal matter is destroyed, and the charcoal derived from the fire consumed; the bones then contain nearly 4-5ths of *phosphate of lime*. They are then reduced to a fine powder, and 2-3rds of their weight of strong sulphuric acid are added, with sufficient water to form a thin paste. On heating this mixture gently for several days, the phosphate of lime is decomposed; the sulphuric acid combines with the greater part of the lime, forming an insoluble sulphate of lime, while another salt, the super-phosphate of lime, together with phosphoric acid, is held in solution. The insoluble sulphate of lime is then separated by filtration, and the acid

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91. What is phosphorus? In what forms does it occur in nature? How does it appear that phosphorus is the connecting medium between organization and the mineral constituent?—92. How is phosphorus prepared?

solution is evaporated to the consistence of a syrup, mixed with a fourth of its weight of powdered charcoal, and strongly heated in an earthen retort. The charcoal withdraws the oxygen from the phosphoric acid, forming carbonic oxide, which is disengaged, while vapours of *phosphorus* pass over, and are condensed in water, into which the beak of the retort is introduced. The phosphorus is then purified by melting it in hot water, and pressing it through chamois leather; or by a second distillation.

93. *Properties of Phosphorus.*—Pure phosphorus is a soft amber-coloured solid, the cut surface of which has a waxy lustre. It melts at 108°, it boils at 550°, and is converted into a colourless vapour. When fused at 150°, and suddenly cooled by being plunged in cold water, it appears black; but it recovers its original colour by fusion and gradual cooling. Phosphorus is exceedingly *inflammable.* Exposed to the air, it is gradually consumed, emits white vapours of a garlicky odour, and appears luminous in the dark; hence, it should always be preserved under water. The combustion of phosphorus in pure oxygen does not take place, unless its temperature is about 80°; but it takes place at as low a temperature as 60°, if the oxygen be diluted with nitrogen, hydrogen, or carbonic acid gas. A very slight degree of heat is sufficient to inflame phosphorus in the open air. Gentle pressure between the fingers, friction, percussion, or a temperature not much above its point of fusion, kindles it readily. Letters or lines traced with it on paper appear luminous in the dark; but there is danger in handling it, as it often takes fire, and produces a very severe burn.

94. *PhosphoricAcid.*—When phosphorus is slowly burned in air, the principal product is *phosphorous acid;* this, however, presently absorbs oxygen, and is converted into phosphoric acid.—1. Phosphoric acid may be conveniently obtained by setting fire to about a drachm of phosphorus in a little metallic cup, placed on a large plate, and immediately covered by a very large dry bell jar. The phosphorus is converted into white flakes of phosphoric acid, which fall upon the plate like snow.—2. Phosphoric acid may be pre-

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93. What are the properties of phosphorus? By what circumstances is its *combustion* determined?—94. What is phosphorous acid? What is phosphoric acid? How may it be prepared? What are the properties of phosphoric acid?

pared at a cheaper rate from bones. These are to be calcined, reduced to powder, and mixed with oil of vitriol diluted with water, as described for the preparation of phosphorus. The filtered solution is then boiled for a few minutes with carbonate of ammonia; a phosphate of ammonia is thus formed, which, on being evaporated to dryness, and heated to redness in a platinum crucible, yields a hydrated phosphoric acid in a fused state. This is termed *glacial phosphoric acid*, from its resemblance to ice. From all that has been ascertained upon the subject, it appears that phosphoric acid has hitherto been obtained only in combination with water, or some alkaline base.—Phosphoric acid is colourless, and of an intensely sour taste; it reddens litmus strongly, and neutralizes alkalies; but it has no corrosive effect upon the skin.

95. *Experiments.*—(1.) If any light substance capable of conducting heat be placed upon the surface of boiling water, and a piece of phosphorus be laid upon it, the heat of the water will be sufficient to set the phosphorus on fire.

(2.) Put a piece of phosphorus into a small phial, then fill it one-third with boiling olive oil, and cork it close. Whenever the stopper is removed during the night, a sufficient quantity of light will be evolved to show the hour upon a watch.

(3.) Pour a little phosphuretted ether upon a lump of sugar, and drop it into a glass of water, a little warm. The surface of the water will soon become luminous; and, if it be moved by blowing gently with the mouth, beautiful and brilliant undulations of its surface will be produced, exhibiting the appearance of a liquid combustion.

(4.) Put thirty grains of phosphorus into a Florence flask with three or four ounces of water. Place the vessel over a lamp, and give it a boiling heat. Balls of fire will soon be seen to issue from the water, after the manner of an artificial fire-work, attended with the most beautiful coruscations.

CHAPTER VIII.

OF CHLORINE.

96. *General Remarks.*—Chlorine, in its elementary state, is a *gas;* but in this state it never occurs naturally. It is found, however, in great abundance in a state of combination, constituting about 60 per cent. of *common salt;* hence, the properties of the waters of the ocean depend upon the universal diffusion of this element throughout them. Chlorine was discovered by Scheele, who termed it *dephlogisticated marine acid;* by the French chemists it was called *oxy-muriatic acid;* but, according to the new theory, it was determined by Davy to be a simple element; the name it now bears is derived from χλωρὸς, *chloros*, green, in allusion to its yellowish-green colour.

97. *Mode of preparing Chlorine.*—Chlorine gas is conveniently prepared by the action of *hydrochloric acid* upon *peroxide of manganese.* (Hydrochloric acid, or muriatic acid, as it is also called, is a solution in water of hydrochloric gas, a compound of chlorine and hydrogen. Peroxide of manganese consists of the metal of this name in its highest state of oxidation.) On mixing in a flask 2 ounces of the peroxide with 6 ounces of the acid, diluted with 1 or 2 ounces of water to prevent it from fuming, effervescence takes place, with the escape of gas, without the application of heat; the evolution of the gas is, however, greatly promoted by the application of a gentle heat. The gas should be collected in inverted glass bottles over warm water at a temperature not below 90°; cold water absorbs the gas, which then evaporates from the surface of the water in the pneumatic trough, to the great annoyance of the operator. The bottles, when filled, should be carefully closed, under water, with ground glass stoppers. The chlorine is freed from a portion of hydrochloric acid which passes over with it, by being washed with water. It is then pure chlorine gas. The *changes* which take place in this process are determined by the mutual affinities of oxygen and hydrogen,

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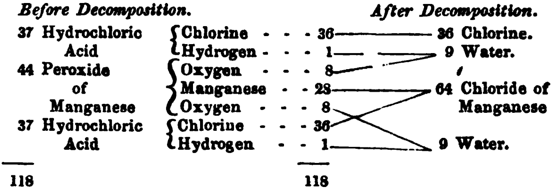
96. What is Chlorine? In what form does it principally occur in nature? By what other names has it been designated?—97. By what process may it be prepared? Explain the *changes* which take place in the process.

and of chlorine and manganese. They may be studied in the following *diagram* :—



98. *Properties of Chlorine.*—Chlorine is a dense gas, of a yellowish-green colour, astringent taste, and suffocating odour, occasioning great irritation of the throat, even when largely diluted with air. It possesses no acid properties, and has little disposition to unite with alkalies. When forcibly and suddenly compressed, it emits heat and light, the latter being occasioned by chemical action of the chlorine upon the oil, by means of which the compressing apparatus is lubricated. Under a pressure of about four atmospheres, chlorine gas is *condensed* into a limpid yellow *liquid*, which does not freeze at the temperature of zero, and which resumes the gaseous form with a kind of ebullition on removal of the pressure.

99. Chlorine does not combine directly with *oxygen;* these elements may be made to combine, but their mutual attraction is so feeble, that very slight causes effect their separation. Chlorine has a powerful attraction for *hydrogen*, and forms with it an important compound, called *hydrochloric acid.* Chlorine and hydrogen may, indeed, be mixed and preserved in the dark without combining; but combination is determined with explosion by the electric spark, by spongy platinum, by direct exposure to the solar ray, and without explosion in the diffused light of day. Chlorine decomposes water, under the action of light, or at a red heat; and most of the chemical phenomena to which chlorine gives rise, are owing to its decomposing most bodies which contain

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98. What are the properties of chlorine? Under what circumstances may chlorine be reduced to the *liquid* state?—99. Under what circumstances do chlorine and hydrogen combine? What is the action of chlorine upon water? Give an example of the indirectly oxidizing agency of chlorine. Give examples of its being a supporter of combustion.

this element, with the production of hydrochloric acid. If an ignited taper be introduced into a bottle of chlorine, the flame is extinguished, but the stream of oily vapour which rises from the wick is rekindled by the chlorine, and the hydrogenous portion of the combustible burns with a red and smoky flame, which is extinguished on exposure to the air. For the same reason, when chlorine, water, and some other body which has a strong affinity for oxygen, are brought together, water is usually decomposed, its hydrogen combining with the chlorine, its oxygen with the other body. Hence, chlorine is, indirectly, a most powerful oxidizing agent. A slip of paper previously dipped into oil of turpentine, takes fire spontaneously in chlorine gas, and deposits a large quantity of carbon. Phosphorus becomes spontaneously ignited in chlorine, and burns with a pale white light. Several of the metals, in the state of powder or thin leaves, are suddenly inflamed in this gas. Hence, chlorine is termed a supporter of combustion.

100. One of the most important properties of chlorine is its *bleaching* power. It destroys all animal and vegetable colours, and these, when discharged, cannot be restored; in this respect, chlorine differs remarkably from sulphurous acid. If a coloured flower, or a green leaf, be introduced into chlorine, the colour suddenly disappears. Hence, chlorine, in combination with lime, is much employed as a discolouring agent in the modern process of bleaching cotton goods. If a portion of *bleaching powder*, or chloride of lime, be mixed with water in a wine-glass, and a small piece of printed muslin be dipped into it, and the glass left for some time in the sun, the muslin will assume a dingy white appearance. It has been proved by Davy that chlorine will not bleach unless water is present: dry litmus paper undergoes no change in dry chlorine; but, when water is present, the colour is rapidly discharged; and it has been also proved that in all cases in which chlorine bleaches, hydrochloric acid is formed. Hence it is inferred, that, in this process, water is decomposed, that its hydrogen unites with the chlorine, and that the decomposition of the colouring matter is occasioned by the oxygen which is liberated.

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100. In what respect does chlorine differ from sulphurous acid, with regard to its *bleaching* property? Under what circumstances is chlorine a bleaching agent? What is *bleaching powder*?

101. *Experiments.*—(1.) If a few strips of dyed linen cloth, of different colours, be dipped into a phial of chloric acid (a compound of chlorine and oxygen), the colours will be quickly discharged. Few colours can resist the energetic action of this acid.

(2.) Fill a glass jar, such as is generally used for deflagrating the gases, with chlorine gas. If nickel, arsenic, or bismuth, in powder, be thrown into this gas, and the temperature of the atmosphere be not lower than 70°, the metal will inflame and continue to burn with the most brilliant combustion.

CHAPTER IX.

OF IODINE.

102. *General Remarks.*—Iodine is a crystallized solid, much resembling chlorine in some of its properties. Both are of marine origin, the latter existing in sea-water, the former chiefly in sea-plants, as in the fuci, the ulvæ; it also occurs in the oyster and in sponge. Iodine exists also in one mineral, a silver ore of Albaradon in Mexico. Iodine occurs in small quantities, and always in a state of combination. The name *Iodine* is derived from ἰώδης, *iódes*, violet-coloured, in reference to the beautiful violet-coloured vapour which it forms on volatilizing.

103. *Mode of preparing Iodine.*—The Iodine of commerce is procured from *kelp*, the ash which remains on incinerating sea-weeds. The sea-weeds are dried, and then burned in a shallow pit, in which the ashes accumulate and fuse into a mass, which, when broken into lumps, constitutes *kelp*, and is employed by soap-manufacturers for making carbonate of soda. After this salt has crystallized from solutions of kelp, a dark oily liquor remains, called the *iodine ley*, which contains in a small bulk the iodine which was previously associated with the kelp. In this ley, the iodine exists in the form of *hydriodic acid*, a compound of

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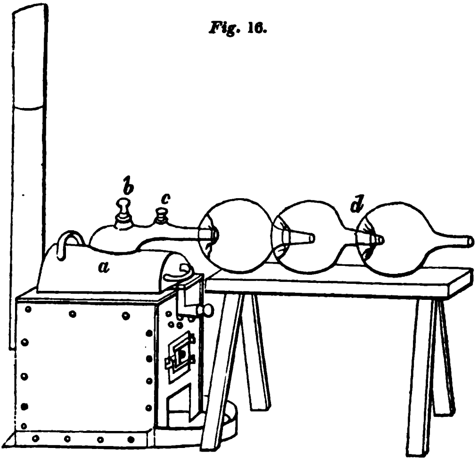
102. What is Iodine? In what substances is it found in nature? What is the origin of the term?—103. From what substance is the iodine of commerce procured? Explain the process by which it is prepared

iodine and hydrogen, in combination with soda. Sulphuric acid is added to liberate the hydriodic acid; sulphate of soda is thus formed, and separated by crystallization, and several gases are expelled at the same time. Hydriodic acid is thus procured in an impure form, and in solution. The ley, so prepared, is heated with peroxide of manganese, in order to separate the iodine.

104. The *apparatus* employed for this purpose is represented in the subjoined figure. The prepared ley is introduced into a leaden retort *a*, of a cylindrical form, supported in a sand-bath, which is heated by a small fire below.

Fig. 16.



The retort has a large opening at the top, to which is fitted a head *b c*, having two openings *b* and *c*, each closed by a leaden stopper. A series of bottles, each with two openings, connected together as represented in the figure, are used as condensers. The prepared ley being heated to about 140° in the retort, the manganese is introduced, and the head is then *luted* to the opening of the retort. Iodine immediately be-

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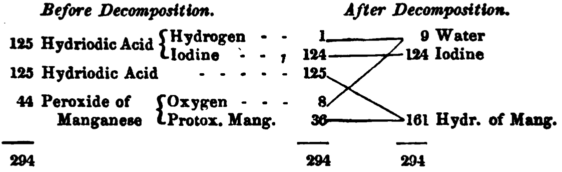
104. Explain the *changes* which take place in this process.

gins to come off, and passes into the condensers. Additional quantities of sulphuric acid or manganese are introduced occasionally at *b*, if required.—The changes which take place in this process are the following. Iodine exists in the form of hydriodic acid; on heating this with peroxide of manganese, one portion of the acid unites with protoxide of manganese, separating oxygen; this decomposes the rest of the hydriodic acid, by uniting with its hydrogen, and the iodine is liberated. The following *diagram* exhibits these *changes*:—



105. *Properties of Iodine.*—Iodine is a soft opaque solid, of a bluish-black colour, usually in the form of crystalline scales. It fuses at 225°, and boils at 347°; but it gradually evaporates at the common temperature, and more rapidly when moisture is present, diffusing an odour resembling that of chlorine. Its vapours are of a beautiful violet colour, which may be seen to great advantage when a portion of iodine is thrown upon a hot brick. Pure water dissolves about 1-7000th of its weight of iodine, and acquires a brown colour; alcohol and ether dissolve it freely, and assume a deep reddish-brown colour. Iodine has an acrid taste, and stains the skin of a yellow colour, which however disappears in a few hours. It acts energetically on the animal system as an irritant poison, but is employed medicinally with great advantage in minute doses. Iodine is a non-conductor of electricity; and, like oxygen and chlorine, is a negative electric. It is not inflammable; but, like chlorine, may be made under favourable circumstances to combine with oxygen. It destroys vegetable colours, though in a less degree than chlorine. It has a strong attraction for the

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105. What are the properties of Iodine? In what respects does it resemble chlorine? By what means is the presence of Iodine detected? What is the value of the *test?*

pure metals, and for most of the simple non-metallic substances, producing compounds which are called *iodides* or *iodurets*. Iodine combines with oxygen, but its compounds are of little importance. Pure iodine is unaffected by the imponderable agents. The presence of iodine is indicated by its violet-coloured vapour. But its presence is most delicately tested by *starch*, with which it forms an insoluble compound of a deep-blue colour; so delicate, indeed, is this *test*, that a liquid containing 1-450,000th of its weight of iodine receives a blue tinge from a solution of starch.

CHAPTER X.

OF BROMINE, FLUORINE, BORON, SELENIUM, AND SILICON.

106. *Bromine.*—Bromine, under ordinary circumstances, is a deep red-coloured liquid, formerly called *muride;* its present name is derived from *βρῶμος*, *bromos*, a rank odour, in reference to its strong and offensive scent. It exists principally in solution, being present in very minute quantities in sea-water in combination with sodium or magnesium, in the water of the Dead Sea, and in nearly all the saline springs of Europe. It occurs also in marine plants growing on the shores of the Mediterranean, and in the ashes of sea-weeds which yield iodine. It has also been discovered in the ashes of some molluscous animals. The chemical relations of bromine are very analogous to those of chlorine and iodine; with the former of these it is always found associated in nature, and sometimes with the latter. Bromine, like chlorine, possesses *bleaching* properties, and discharges the blue colour from a solution of indigo. Some inflammable substances take fire by contact with bromine, in the same manner as when introduced into chlorine. Bromine acts powerfully on organic substances,

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106. What is *Bromine?* What is its derivation? How does it occur in nature? What are its properties? In what respect does it resemble chlorine?

corroding the animal texture, and imparting a transient yellow stain to the skin. It is destructive to animal life: a drop placed on the beak of a bird has proved fatal. Bromine forms a yellow compound with *starch*, which affords a valuable *test* of its presence.

107. *Fluorine.*—Very little is known of Fluorine. It has not hitherto been obtained in an elementary state; its existence, therefore, has been rather inferred than proved. It occurs principally in the mineral called *fluor-spar*, in a state of combination with lime. A trace of it also occurs in the enamel of the teeth, and in the bones of animals. Fluorine, like oxygen and chlorine, appears to have a strong affinity for hydrogen and metallic substances. *Hydrofluoric acid*, the compound of fluorine and hydrogen, is the most destructive of all known substances to animal matter: a drop of the concentrated acid applied to the skin produces immediate disorganization and malignant ulceration. The diluted solution, or the vapour of hydrofluoric acid, acts energetically on glass, and is sometimes employed for the purpose of *etching* on this material.

108. *Boron.*—Boron, in its elementary state, is a deep brown powder, and has some analogy to carbon. It is only found in combination with oxygen, in the form of *boracic acid*, which in the condition of a salt of soda, is brought from India in a crude state under the name of *tinkal*, and, when purified, is termed *borax*. Borax exists in small quantities; in the impure state, it forms a saline incrustation in the beds of some small lakes in Thibet, which dry up during summer. Free boracic acid occurs in more considerable quantities in a district of Tuscany, where it is condensed from vapours of volcanic origin. Boracic acid is found in the hot springs of Lipari. It enters also into the composition of several minerals.

109. *Selenium.*—Selenium is a brittle, opaque, solid substance, generally found associated with sulphur. It is one of the least abundant of the elements, but is found in minute quantity in the ores of several metals in Sweden and Norway. It is sometimes detected in sulphuric acid. Sele-

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107. In what state does *Fluorine* occur naturally? What is hydrofluoric acid? What are its properties?—108. What is *Boron?* In what form is it found in nature? What is *tinkal?* What is *borax?* Whence is borax procured? Where is boracic acid found?—109. What is *Selenium?* To what elementary substance is Selenium allied? What is the origin of the term?

nium somewhat resembles sulphur in its properties; or, rather, it appears to be a kind of connecting link between sulphur and the metals. The process by which Selenium is separated from its combinations with sulphur and metals is very complicated, and cannot here be described. Its name, Selenium, is derived from σελήνη, *selené*, the moon, on account of its strong analogy to another element, tellurium, which derives its name from *tellus*, the earth.

110. *Silicon.*—Silicon is the elementary basis of *silex* or common flint, one of the most abundant minerals in nature, constituting the groundwork, as it were, of our globe. It does not exist in an elementary state. It is procured in the form of a brown powder, and much resembles boron in appearance; these two substances appear to be more nearly allied to carbon, than to any other elementary body. By combustion, silicon combines with oxygen, and is converted into *silex*, which is by some chemists considered to be an acid. Silex is found in small quantities both in plants and animals; but does not, like oxygen, hydrogen, nitrogen, and carbon, form a constituent element of organized beings.

111. Silicon combines with oxygen in the proportion of one equivalent of the former to three of the latter, and forms *Silicic acid.* This compound, which is known also by the names *Silica* and *siliceous earth*, enters into the composition of most of the earthy minerals; it is the chief ingredient of sand, and of the varieties of sandstone, of calcedony, rock crystal, &c., and, under the name of *quartz*, forms independent rocky masses. Silicic acid forms several important compounds, called *silicates*, with the fixed alkalies and various metallic oxides. Every kind of ordinary glass is a silicate; the varieties of glass depend on the nature of the alkali or oxide, the proportions of the constituents, and the admixture of foreign matters. Thus, with three parts of carbonate of potassa and one of silica, a glass is formed which is soluble in water and deliquescent; if an excess of silica be employed, the glass is insoluble in water. *Common bottle glass* consists of impure silica, as common sea or river sand, which contains iron, and the most common kind of kelp or pearl-ash. *Window-glass* is made from a purer silica and a purer alkali. *Plate-glass*, employed for

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110. What is *Silicon?* What is *Silex?*—111. What is *Silica?* State the composition of the different kinds of *glass.*

looking-glasses, is made from sand and alkali in their purest state. *Flint-glass* contains, besides these pure ingredients, a considerable quantity of red lead. *Flint-soap* is a variety of silicated alkali, produced by boiling finely powdered flint with potassa or soda.

CHAPTER XI.

OF CERTAIN COMPOUNDS OF HYDROGEN WITH THE NON-METALLIC ELEMENTS.

112. *Ammonia.*—Ammonia is a compound of hydrogen and nitrogen, and may be procured from a mineral substance, well known under the name of *Sal-Ammoniac* from its having been first prepared in the district of Ammonia, in Libya; in chemical language it is termed, *muriate of ammonia.* If some of this substance be pulverized, and mixed with an equal portion of unslaked quick-lime, also in the state of powder, and the mixture be introduced into a glass flask *a*, into the mouth of which is inserted a tube of a foot or more in length; if a tall bell-glass *b*, be inverted over the tube, and gentle heat applied to the flask, the muriatic acid of the muriate of ammonia will combine with the lime, and *ammonia* be set at liberty; this gas being lighter than atmospheric air, will ascend, gradually displace the air from the bell-glass, and take its place. Ammonia, as thus produced, is a colourless gas, consisting of 1 vol. of nitrogen and 3 vols. of hydrogen, which, by combination, are condensed into *two* volumes of the compound gas.

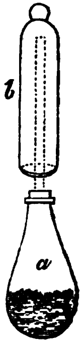

Fig. 17.

113. Ammonia possesses all the properties of an alkali in a very marked degree, and is often called the *volatile alkali*, a term denoting that it is *raised* by distillation, and distin-

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112. What is Ammonia? How may it be prepared?—113. What are the properties of ammonia? Why is it called the volatile alkali? What is spirit of hartshorn?

guishing it from the *fixed alkalies*, potash and soda, which are *left* in the ashes of inland and marine plants respectively. Water absorbs several hundred times its bulk of this gas: a piece of ice introduced into a jar of ammonia is instantly liquefied, and the gas disappears in a few seconds. The concentrated solution of ammonia, formed by transmitting the gas into distilled water, so long as it continues to be absorbed, is well known as the pungent liquid called *spirit of hartshorn*, being generally prepared from the horns of animals, and other animal matters; it is also called *liquor*, or *aqua ammoniæ;* and incorrectly, *liquid ammonia.* Under a pressure equal to 6·5 atmospheres, and at the temperature of 50°, ammonia is condensed into a transparent colourless *liquid;* on removing the pressure, it again expands and assumes the gaseous state. Ammonia, in a pure state, is irrespirable. It extinguishes the flame of burning bodies, and is itself inflammable in a very low degree.

114. *Light Carbureted Hydrogen.*—This gas, frequently termed *heavy inflammable air*, *marsh-gas*, and *fire-damp*, consists of hydrogen and carbon, and may be readily procured by stirring the mud at the bottom of stagnant pools, and collecting the gas, as it escapes upwards, in an inverted glass vessel. In this state it contains 5 per cent. of carbonic acid gas, which may be removed by means of lime-water; and nearly the same proportion of nitrogen. Light carbureted hydrogen often accumulates in coal mines, where, through defective ventilation, it gradually mingles with atmospheric air, and forms a mixture which explodes by the contact of flame. Light carbureted hydrogen consists of 1 vol. of *carbon vapour* and 2 vols. of hydrogen; but its combining measure and equivalent are unknown. It is a tasteless, and nearly scentless gas; it is irrespirable, and it extinguishes the flame of all burning bodies; it is highly inflammable, and burns with a strong yellow flame.

115. *Safety Lamp.*—The accidents, formerly so frequent and so fatal in coal mines, arising from explosions of light carbureted hydrogen, led to the invention of the *Safety Lamp.* Davy found that the inflammable gas would not

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114. What is light carbureted hydrogen? In what situations does it occur? —115. Upon what principles was the safety lamp constructed? Explain the construction of the safety lamp.

explode, if mixed with less than 6, or with more than 14 times its volume of atmospheric air; that neither red-hot iron nor red-hot charcoal was capable of exploding it; that the explosive mixture could not be fired in tubes of 1-7th of an inch in diameter; and that metallic tubes prevented explosion better than tubes of glass. Upon these principles he constructed the *Safety Lamp*, a figure of which is here represented. A piece of fine *wire-gauze* may be regarded as an assemblage of short narrow tubes, which are impermeable to flame; consequently, a lighted lamp, completely surrounded by a cage of *wire-gauze*, may be introduced into the explosive atmosphere, without fear of kindling it. Further than this, the safety lamp indicates to the miner the precise moment of danger. When carried into an atmosphere of light carbureted hydrogen, the flame of the lamp begins to enlarge; and the mixture, if highly explosive, takes fire as soon as it has passed through the wire-gauze, and burns on its inner surface, while the flame of the lamp itself is extinguished. This is the signal for the miner to withdraw; for, although the flame should not be able to communicate with the explosive atmosphere surrounding the *outside* of the lamp, so long as the texture of the gauze remains entire, yet the heat evolved during the combustion *within* is so great, that, in a few minutes, the wire would undergo oxidation and fall to pieces.

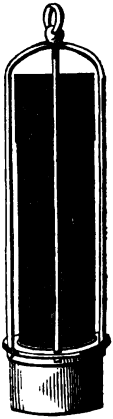

Fig. 18.

116.—*The principle upon which wire-gauze prevents the communication of flame*, may be readily explained. Flame is gaseous matter heated so intensely as to become luminous; and Davy found that this degree of heat is greater than that of solid bodies heated to whiteness. Now, the metals are rapid conductors of heat; when the flame, therefore, comes in contact with the wire gauze, its temperature is so reduced by the conducting power of the metal, that, although the gas passes freely through the interstices, and

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116. Explain the principle upon which wire-gauze prevents the communication of flame. Illustrate this principle by experiments.

is still very hot, it is not sufficiently so to become luminous. That wire-gauze does completely intercept the flame of a burning body, may be proved by the following simple experiments. 1. If a piece of thick iron or brass wire be bent into a little ring, as represented in the figure, and this ring be gradually lowered over the flame of a candle until it surrounds the wick, the flame will be extinguished, owing to the wire conducting away the heat with such rapidity, that the gaseous matter is cooled below the temperature necessary for flame. 2. If a piece of wire-gauze be placed over the flame of a lamp, as in the subjoined figure A, the hand may be applied *above the gauze* as near to the flame as possible, without injury; but, on removing the gauze, the heat cannot be endured by the hand in this position for a moment. 3. If a bottle be filled with an inflammable gas, and a slender pipe be fitted to its neck, the gas may be inflamed as it escapes. If a piece of wire-gauze be held over the flame, as at A, the flame will be flattened, but will not pass through the gauze. If, on the other hand, the gas be inflamed *above the gauze*, as at B, it will burn freely, but the flame will not be communicated through the gauze to the contents of the pipe. 4. It is also found that the flame of coal-gas is incapable of passing through a sheet of wire-gauze, containing not fewer than 400 holes in the square inch.

Fig. 19.

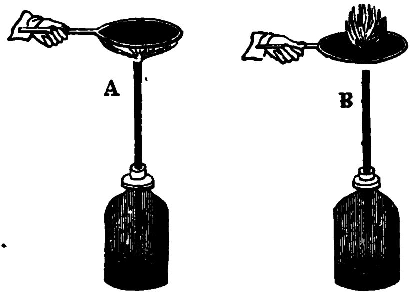

Fig. 20.

117. *Coal and Oil Gases.*—These gases are procured from coal and oil, by heating them to redness in an iron retort. The *illuminating power* of a gas is in proportion to the quantity of carbon it contains. Thus, the flame of pure *hydrogen* affords a very feeble light; when combined with one proportion of carbon, in the form of *light carbureted hydrogen*, its light is greatly increased; and, when combined with another proportion of carbon, in the form of *olefiant gas*, it affords a brilliant and intensely luminous flame. It is also found that, the greater the density of the gas, the richer it is in carbon, and the more brilliant, consequently, will be its flame. The comparative illuminating powers of gases may, therefore, be estimated, by determining the relative quantities of the denser carburets of hydrogen which enter into their composition. *Coal-gas* contains less of the heavy carburets of hydrogen than *oil-gas*, and has, therefore, feebler illuminating powers. *Oil* consists principally of carbon and hydrogen, and therefore yields a gaseous product of comparative purity. *Coal*, on the other hand, contains a large quantity of oxygen and nitrogen, and hence, besides the heavy carburets of hydrogen, numerous compounds are formed, which are not only useless, but positively prejudicial to illumination.

118. *Structure of Flame.*—It has been already observed that *flame* is gaseous matter heated so intensely as to become luminous. Hence, the more completely the gaseous matter is consumed, the more intense and perfect will be its light. This will be readily understood from considering the *structure of flame*. The flame of a spirit lamp, of a candle, or of a gas jet, consists of three parts, or cones, as represented in the adjoining figure. 1. The innermost part, *a*, is a hollow cone, and consists of the combustible material in a state of vapour. 2. The intermediate part, *b*, is the luminous portion of the flame. The combustion of the materials is, however, not complete in this part, the supply of air being insufficient for that

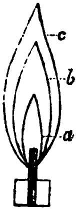

Fig. 21.

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117. Upon what does the illuminating power of a gas depend? State the comparative illuminating powers of hydrogen, light carbureted hydrogen, olefiant gas, coal-gas, and oil-gas.—118. What is flame? Describe the three parts of which a flame consists. What is the deoxidizing flame? Which is the oxidizing flame?

purpose; it is the hydrogen principally which burns, the carbon being separated in solid particles, which are heated white hot from the combustion of the gas, and give the luminousness to the flame; hence, Davy described luminous flame as always containing *solid matter heated to whiteness.* This part of the flame, possessing an excess of combustible matter at a high temperature, is a powerful agent in removing oxygen from metallic oxides, and reducing them to their metallic state. Hence this portion is called the *deoxidizing flame.* 3. In the external cone, *c*, the deposited carbon meets with oxygen from the surrounding atmosphere, and is entirely consumed. The greatest heat of the flame is found within this cone, near the point of *b.* The outermost part of the flame, being mixed abundantly with the oxygen of the air at a high temperature, is the proper part for kindling a combustible, and is called the *oxidizing flame.* Its properties are the reverse of those of the intermediate cone. According to the above account, *a* represents a cone of vaporized combustible; *b*, the sphere of partial combustion; and *c*, the sphere of complete combustion.—*Graham's Chemistry*, p. 424.

119. *Argand Burner.*—In the *Argand Burner*, which is a lamp with a circular wick, and named from its inventor, complete combustion is promoted, by allowing the air to enter freely *within*, as well as on the outside of the inflammable matter. A result of the circumstances which determine the quantity of light from different flames, is, that the larger the flame till it begins to be smoky, the greater is the proportion of light obtained from the consumption of the same quantity of gas. It has been found that an Argand burner, supplied with 1½ cubic foot of gas per hour, gives as much light as a single candle; with two cubic feet per hour, the light is equal to that of four candles; and with three cubic feet, to that of ten candles. Hence Argand and other burners, in which a considerable quantity of gas is burned together, are more economical than plain jets.

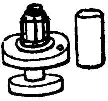

Fig. 22.

120. *Sulphureted Hydrogen.*—Sulphureted hydrogen, or *hydrosulphuric acid*, is a gas, consisting of hydrogen and

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119. What is the principle of the Argand burner?—120. What is sulphureted hydrogen? How may it be prepared? What are its properties?

sulphur, which is evolved in great quantities from the earth in volcanic districts, and in smaller quantities from decaying animal matters. The gas may be procured by the action of sulphuric acid upon sulphuret of iron. It consists of 2 vols. of hydrogen, and 1-3rd vol. of sulphur vapour, which are *condensed*, by combination, into 2 vols. of the compound gas. Under a pressure of 17 atmospheres at 50°, sulphureted hydrogen is condensed into a limpid colourless *liquid*, which resumes the gaseous form on removal of the pressure. This gas is very injurious to animal life: birds perish in an atmosphere containing 1-1500th, a dog in air containing 1-800th, and a horse in air containing 1-250th, of its volume of this gas. Sulphureted hydrogen extinguishes flame, but is itself highly combustible, burning with a pale-blue flame; its combustion is attended by the formation of water and sulphurous acid, and the deposition of sulphur. *Sulphurous mineral waters* contain this gas, but its proportion is rarely more than 1½ per cent. of their volume.

121. Sulphureted hydrogen is a very valuable *test for metals*. The method employed for this purpose is very simple, and is illustrated in the adjoining figure. The materials for forming the gas may be introduced into a flask, furnished with a bent tube; the metal to be tested is dissolved by means of nitric acid, and the solution placed in a glass. The tube is dipped into the glass, and the gas passes into the solution. If the metal be lead, the solution becomes *black;* if arsenic, *yellow;* if antimony, *red;* if zinc, *white*. Sulphureted hydrogen blackens solutions of many metals besides lead; but these may be distinguished from each other by various tests. Sulphureted hydrogen is a re-agent of frequent application, and is of considerable importance. A solution of sulphureted hydrogen in water may be often advantageously used for testing metals, instead of the gas itself.

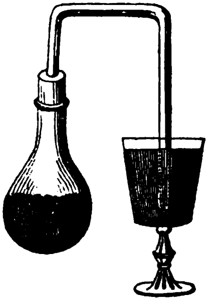

Fig. 23.

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121. Explain the process of testing metals by means of this gas.

122. *Phosphureted Hydrogen.*—Phosphureted hydrogen is a compound of hydrogen and phosphorus, and may be procured by boiling phosphorus, lime, and water together, the hydrogen of the decomposed water combining with a portion of the phosphorus. The gas, as thus procured, takes fire spontaneously on exposure to the air, or to oxygen gas. If the beak of the retort from which it issues be plunged under water, so that bubbles may rise successively through the liquid, a very beautiful phenomenon takes place. Each bubble, on reaching the surface of the water, bursts into flame, and forms a ring of dense white smoke, which enlarges as it ascends, and retains its shape, if the air is tranquil, until it disappears. If the gas be received into a vessel of oxygen, the entrance of each bubble is instantly followed by a strong concussion, and a flash of white light of extreme intensity.

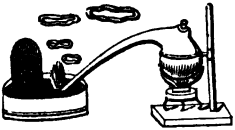

Fig. 24.

123. *Hydrochloric Acid Gas.*—This gas, known by the names of *marine* and *muriatic acid*, is a compound of hydrogen and chlorine, and may be prepared by mixing together equal measures of these gases, and exploding the mixture by flame, by the electric spark, or by spongy platinum. Combination of the mixed gases also takes place, with explosion, under the direct solar ray; in diffused daylight, it takes place gradually. Hydrochloric acid is also prepared by the action of oil of vitriol on common salt; on heating equal parts of these substances in a retort, the gas comes over, and may be condensed in a receiver. Hydrochloric acid has a powerful attraction for water; exposed to the air it condenses aqueous vapour, and escapes in the form of dense white fumes. If a piece of ice be introduced into a jar of this gas, it is immediately liquefied, and the whole of the gas disappears in a few seconds. On opening a long and wide jar of this gas under water, the absorption of the gas is so instantaneous, that the water rises in the jar with the same violence as it would into a vacuum. The

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122. How may phosphureted hydrogen be procured? What phenomenon takes place, on its exposure to the air?—123. How may hydrochloric acid gas be prepared? What is aqua regia? What is its peculiar property?

hydrochloric acid of commerce is an aqueous solution, formed by transmitting the gas into water, so long as any of it is absorbed. A mixture of two measures of this acid and one of nitric acid constitutes *aqua regia*, which is well known for its property of dissolving gold and platinum.

OF THE METALLIC ELEMENTS.

CHAPTER XII.

GENERAL CONSIDERATIONS OF METALS.

124. *General Remarks.*—There are forty-three *Elementary Metallic Bodies.* Of these, seven only were known to the ancients, viz., gold, silver, iron, copper, mercury, lead, and tin; most of the others are of recent discovery. The metals are distributed in vast quantities throughout the globe, and present a variety of forms, according to the substances with which they are found associated, as oxygen, chlorine, sulphur, and several acids. Metals seldom occur in an elementary state, but are separated from their compounds by difficult and complicated processes. When they occur in the pure state, they are termed *native;* when they are associated with other bodies, they are said to be *mineralized;* the combination of a metal with a mineralizing substance, is called an *ore.* Ores are found in large fissures in rocks, termed *veins;* and often in beds of earth. Combinations of the metals with each other are called *alloys;* these possess all the characteristic physical properties of the pure metals; when mercury is one of the constituents, the

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124. How many elementary metallic bodies are known? Which of them were known to the ancients? In what state do the metals usually occur in nature? How are they designated, when they occur pure? How, when associated with other substances? What is meant by an ore? What is an alloy? What is an amalgam? How are the metals affected with regard to heat, to light, and to electricity? What bodies are formed by combinations of the metals with oxygen? Explain the manner in which the metals have been arranged.

compound is called an *amalgam*. All the metals are conductors of heat and of electricity; they are all positive electrics. They are lustrous, opaque, and refuse to transmit light: but they are in general good reflectors of light. Metals, like the simple non-metallic bodies, combine with oxygen, and form *acids* and *oxides;* the latter are the more frequent products. A *Plan of Arrangement of the Metals* has been already given at p. 22 of this treatise.

I. GENERAL PROPERTIES OF METALS.

125. *Hardness and Elasticity.*—Metals are generally very *hard* substances; among the hardest are placed iron, zinc, copper, manganese, nickel, titanium, and palladium; gold, silver, and platinum, are of a softer quality; lead is still softer than these; and potassium and sodium are so soft as to yield to pressure of the finger. The property of *elasticity* is connected with that of hardness, the hardest metals being also the most elastic. The *sonorous* quality of metals is allied to their hardness and elasticity; in these respects, iron and copper are conspicuous.

126. *Density.*—The most *dense* substances in nature are found among the metals. Gold, for instance, is upwards of 19 times, and platinum nearly 21 times, heavier than an equal bulk of water. But density is not an essential character of metals: potassium and sodium are so light as to float upon the surface of water. Some metals become denser on being hammered, their particles being brought together permanently by the operation.

127. *Crystalline Texture.*—Many of the metals are capable of assuming crystalline forms, which are, generally, those of the *cube* and the *octohedron*. The facility of procuring metallic crystals is proportionate to the lowness of the temperature at which a metal fuses: bismuth conducts heat less perfectly than other metals, and therefore yields crystals

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125. Enumerate some of the metals with reference to their comparative hardness. What relation exists between the hardness and the elasticity of metals? What other quality of metals is allied to their hardness and elasticity?—126. What is the density of gold, and of platinum, as compared with that of an equal bulk of water? What metals are so soft as to float upon water?—127. What are the common crystalline forms assumed by metals? To what is the facility of procuring metallic crystals proportionate? What is the texture of iron, and of antimony?

most readily. The texture of iron is *fibrous;* that of zinc, bismuth, and antimony, *lamellated*, or in minute plates.

128. *Malleability.*—Many of the metals are capable of being extended into thin plates or leaves under the hammer, and are termed *malleable* metals. This property depends upon a high degree of *tenacity* connected with a certain degree of *softness.* Gold is the most malleable of the metals: a grain of gold may be extended so as to cover 50 square inches of surface, and to have a thickness not exceeding 1-282,020th of an inch; it may thus present two millions of visible points. Zinc is malleable in the highest degree between 300° and 400°; and iron at a temperature exceeding that of a red heat. Some metals are either very slightly malleable, or, like antimony, arsenic, and bismuth, actually brittle. Metals which have become brittle, either in consequence of fusion, or of long-continued hammering, are again rendered malleable by *annealing*—the process of heating a metallic body, and allowing it to cool in a moderate temperature. A few of the malleable metals can be *welded*, or portions of them joined together by hammering. Iron and platinum may be welded together at a bright-red heat, and fragments of potassium may be made to adhere by pressing them together by the hand at the ordinary temperature of the air.

129. *Ductility.*—Most of the malleable metals admit of being drawn out into wire, and are called *ductile* metals. The ductility of metals is, however, not always proportional to their malleability; iron, for instance, may be drawn into very fine wire, but it cannot be beaten into very thin leaves. Wollaston formed a gold wire so thin as to be only 1-5000th of an inch in diameter; 550 feet of it weighed only one grain; an ounce of it would extend fifty miles. He also obtained a wire of platinum of not more than 1-30,000th of an inch in diameter.

130. *Tenacity.*—The tenacity of different metals is deter-

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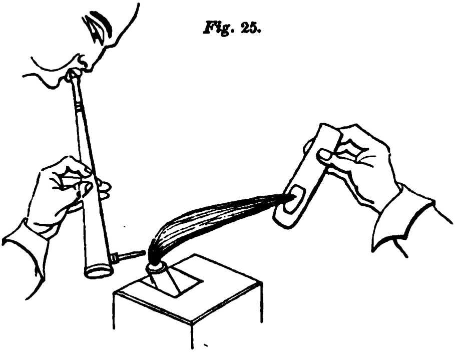
128. What is malleability? On what does this property depend? Which is the most malleable metal? Which are brittle metals? What is meant by the process of annealing? What effect has this process on metals which have become brittle? What is meant by welding?—129. What is ductility? Show that the ductility of metals is not proportionate to their malleability. To what extent has the ductility of gold, and of platinum, been carried?—130. How is the tenacity of metals ascertained? In what metals is this property exhibited in its highest, and in its lowest degree? By what process is the tenacity of metallic wires impaired?

mined by ascertaining the weight which a wire of a certain thickness can support without breaking. This property appears to be highest in iron, and lowest in lead. It has been found that the tenacity of wires of iron, copper, and brass, is much impaired by *annealing* them.

131. *Fusibility.*—The metals, with the exception of mercury, are all solid at the temperature of the air; but they may all be liquefied by heat. The degree at which they *fuse*, or their *point of fusion*, is very different for different metals: some of them are fusible below a red heat, as tin, lead, zinc, &c.; most of them are infusible below a red heat; iron and manganese require for their fusion the highest heat of a smith's forge; and many, as platinum, are fusible only before the oxy-hydrogen blow-pipe.

132. *The Blow-Pipe.*—The *fusibility* of metals is ascertained by means of an instrument called a *blow-pipe.* Every effect of the most violent heat of a furnace may be produced by the flame of a candle or lamp, directed upon a small portion of a metal by this means. This instrument consists of a bent brass tube of about one-eighth of an inch in diameter at one end, and tapering at the other end to a much smaller

Fig. 25.



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131. What is meant by the point of fusion of metals? What metals are fusible below a red heat?—132. What is the blow-pipe, and for what purpose is it employed? In what ways is a substance said to be fusible? Which is the sphere of most complete combustion, in the flame of a lamp or candle?

size, so as to admit the escape of a very fine jet of air. For chemical purposes, the tube is enlarged gradually, as shown in the figure above, to admit of the accumulation of a larger quantity of the breath. The substance to be submitted to the action of the blow-pipe, must be placed upon a piece of charcoal, or in a small spoon of platinum, gold, or silver. When a large flame is required, a lamp with a large wick must be employed, and the air supplied by means of bellows, in the manner adopted by workers in glass. When intense heat is required, the oxy-hydrogen blow-pipe is used. The blow-pipe is chiefly employed to ascertain whether a substance be fusible *per se;* whether it be fusible by heating it with a flux or re-agent; whether it give off volatile matter by heat; whether a metallic oxide be *reducible;* and to ensure a high temperature in the performance of chemical operations on a small scale. The substance to be tried must be placed in the sphere of the most perfect combustion (p. 72).

133. *Alcohol Blow-pipe.*—The vapour of alcohol has been employed in the *self-acting blow-pipe* of Mr. Hooke. This ingenious apparatus consists of a hollow metallic sphere E for containing alcohol, made to rest upon a circular frame. G is a bent tube with a jet at the end, to convey the alcohol in the state of vapour into the flame of the lamp D; this tube is continued upwards inside the sphere almost to its top, so that the sphere may be nearly filled, without any of the alcohol escaping by the tube. F is a safety-valve, the pressure of which is determined by screwing it higher or lower by means of the annexed apparatus. The alcohol is poured into the sphere at a small hole at the top, and it is raised into vapour by means of the lamp beneath.

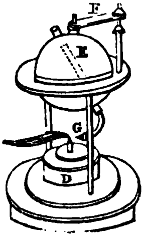

Fig. 26.

134. *Volatility.*—The metals are, in general, highly *fixed* substances. Some of them, however, admit of being dissipated into vapour at high temperatures, and are, indeed, so volatile, as to be occasionally distilled. Seven of the metals

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133. Explain the apparatus, termed the self-acting blow-pipe.—134. What is meant by volatility? What metals are well known to possess this property.

are well known to possess this property, viz. mercury, cadmium, arsenic, tellurium, potassium, sodium, and zinc; it is probable that all the others possess the same property.

II. OXIDATION OF METALS.

135. *Affinity between the Metals and Oxygen.*—All the metals are capable of uniting with oxygen, but they differ considerably in their degree of affinity for this element. Most of them are oxidized by exposure to the air; in these cases, if the metals are in mass, the oxidation is very slow and feeble; but it is complete in the same metals, when reduced to powder. The affinity of potassium and sodium for oxygen is so great, that they decompose water immediately on being brought into contact with it. Iron undergoes no change in dry air, but, in a moist atmosphere, it is slowly oxidized; when heated to redness in the open air, this metal is rapidly oxidized; iron also decomposes water at a red heat. Copper has a feebler affinity, than iron, for oxygen: it is oxidized, like iron, in moist air, and at a red heat, but it does not decompose water at a red heat. Mercury has a still feebler affinity for oxygen: it may be exposed without change to a moist atmosphere. At high temperatures, metals combine rapidly with oxygen, and exhibit the phenomena of real *combustion.* Thus, zinc burns with a brilliant flame, when heated to redness in the open air; iron emits vivid scintillations, when inflamed by a jet of oxygen gas. Gold, silver, platinum, and palladium, do not combine directly with oxygen under any circumstances.

136. *Calcination.*—When a metal has been heated in the open air, it undergoes oxidation, and acquires an earthy aspect. This substance was formerly called a *calx*, from its being earthy, like lime; it is now more commonly called an *oxide;* and the operation, when considered with regard to such fixed residues, is termed *calcination.* In this general acceptation, the term is applied to bodies which are not

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135. What is oxidation? How is the strong affinity of potassium and sodium for oxygen demonstrated? Under what circumstances does iron undergo oxidation? Show that copper has a feebler affinity for oxygen, than iron; and that the affinity of mercury for this gas is feebler still. Do any metals exhibit the phenomena of real combustion? Which metals do not combine with oxygen under any circumstances?—136. What is calcination? To what bodies is the term applied, in its general acceptation? When is chalk said to be calcined? When is the term applied to saline bodies? when, to bones?

really combustible, but which are merely deprived of some of their principles by heat. Thus, when chalk is converted into lime, by expelling its carbonic acid and water, it is said to be *calcined.* When alum, borax, and other saline bodies are deprived of their water of crystallization; or when bones are made to lose their volatile principles by heat; these bodies are sometimes said to undergo *calcination.*

137. *Deflagration.*—Another method of oxidizing metals is by mixing them with nitrate or chlorate of potassa, and throwing the mixture into a red-hot crucible; this process is termed *deflagration;* it is attended by vivid combustion, which may be attributed to the extrication of oxygen from the nitre, or other deflagrating substance, and its communication to the inflammable body. Metallic oxides are also formed by the action of metals on water, on nitric acid, on sulphuric acid; nitro-hydrochloric acid is an agent of great oxidizing power.

III. REDUCTION OF METALS.

138. The term *Reduction* is applied to the operations by which metallic oxides are *reduced* to the metallic state, or metals freed from other substances with which they may be associated. The name *regulus* was formerly applied to metallic matters which have been separated from other substances by fusion; it was afterwards applied to the metal extracted from an ore, as regulus of antimony, of arsenic, of cobalt.

139. *Reduction by Heat alone.* — The oxides of gold, silver, mercury, and platinum, may be decomposed, and reduced to the metallic state by *heat alone,* by means of the blow-pipe (p. 79). If, in this process, the heat be insufficient to melt the metal, it will appear as an earthy powder, without metallic lustre.

140. *Reduction by Heat and Combustible Matter.*—When reduction cannot be effected by heat alone, some combustible matter is introduced to assist in removing the

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137. What is meant by the process of deflagration? To what is the combustion, attendant on this process, attributed?—138. What is meant by reduction? What was the original, and what the secondary, meaning of the term *regulus?* —139. By what means may the oxides of gold, silver, mercury, and platinum, be reduced?—140. When reduction cannot be effected by heat alone, what further means are adopted? What is a flux? In what different ways may a flux act? Describe the several kinds of flux.

oxygen or other matters with which the metal may be associated. 1. The oxides of copper and iron are *reduced* by transmitting a stream of hydrogen gas over them, when heated to redness in a porcelain tube: water is formed, and the metals are reduced to a state of purity. 2. Carbon, in various forms, is generally employed for removing oxygen: potassa and soda are decomposed by exposure to a white heat, after being intimately mixed with finely powdered charcoal. 3. In the metallurgical processes of separating metals from their ores, wood, charcoal, coke, or coal, is the combustible material employed. 4. In chemical operations, it is often necessary to employ some substance which melts readily, and allows the metallic particles, as they are separated, to subside in it and accumulate together. A substance of this kind is termed a *flux*. A flux may act in different ways: it may merely melt, and allow the metallic particles to fall through it; or it may combine, as it melts, with ingredients mechanically mixed, in a minute state of division, with the ore, forming with them a very fusible compound, called a *slag*, through which the reduced metal may fall; or, it may affect chemically some of the ingredients combined with the metal in the ore, forming with them the fluid matter through which the metal is deposited. Alkaline fluxes are generally used; their effect is to render the earthy mixtures fusible by converting them into glass. *Crude flux* is a mixture of nitre and crystals of tartar. *White flux* is a pure carbonate of potassa. *Black flux* is carbonate of potassa mixed with carbon. A very fusible flux for experiments on the small scale is prepared by mixing 5 parts of carbonate of potassa with 4 parts of carbonate of soda.

141. *Reduction by the Galvanic Battery.*—This is a still more powerful agent than the preceding. Some oxides, which resist the united influence of heat and charcoal, may be reduced by the agency of Galvanism. When reduction is effected by this means, the metal always appears at the negative pole of the battery.

142. *Reduction by Deoxidizing Agents.*—Metals are re-

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141. When the galvanic battery is employed for the purpose of reduction, at which pole do the metals always appear?—142. How are metals reduced from solutions of their oxides? Under what circumstances are metals employed for reducing other metals from their combinations? Give some instances of this mode of operation.

duced from solutions of their oxides by means of deoxidizing agents. If phosphorous acid be added to a liquid containing oxide of mercury, oxygen is taken from the oxide, phosphoric acid is formed, and metallic mercury subsides. Metals are occasionally employed for reducing other metals from their combinations, when dissolved in water; in such cases, the affinity of the former for oxygen must exceed that of the latter. Thus, iron precipitates copper from the sulphate in solution, and takes its place. Mercury added to a solution of nitrate of the oxide of silver, precipitates metallic silver, and passes into the state of oxide of mercury, which is dissolved in the nitric acid. On introducing metallic copper into this liquid, pure mercury is thrown down, and a nitrate of the oxide of copper formed; and this may be precipitated by means of iron. In cases in which the metallic compound to be reduced is insoluble in water, decomposition may often be effected by boiling the compound together with the decomposing metal, in water. Thus, zinc, boiled in water with the chloride of silver, combines with the chlorine, and is dissolved; the silver is separated from the insoluble chloride in a minute state of division.

CHAPTER XIII.

OF THE METALS.

DIV. 1. METALLIC BASES OF THE ALKALIES.

143. The alkalies, potassa, soda, and lithia, are oxides of peculiar metals, termed *potassium*, *sodium*, and *lithium*. These are called *kaligenous metals*, from the word *kali*, an old name of potassa, used in a general sense to denote an alkali. They were first procured by Davy, by decomposing their oxides by means of Galvanism; oxygen appeared at the positive, and the metals at the negative, pole of the battery.

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143. What are the names of the fixed alkalies? What is their composition? What is meant by *kaligenous* metals? By whom, and how, were they discovered?

44. **Potassium.**—*Potassium*, or *kalium*, is solid at common temperatures, but it is so soft that it yields to the pressure of the fingers; at 32°, it is brittle; at 150°, it melts; at a temperature below that of redness, it passes into vapour. It is considerably lighter than water, and floats upon this liquid. It has a powerful affinity for oxygen, and oxidizes rapidly by contact with liquids which contain this gas; a fresh surface, exposed to the air, is almost instantly covered by a dull film of oxide. Potassium decomposes water at the instant of touching it, with the evolution of so much heat, that the metal takes fire, and burns vividly as it moves over the surface of the water; the brilliancy of the flame is increased by the combustion of the hydrogen, which takes fire during its separation; a globule of fused *potassa* remains floating on the water, but in a few seconds, as its temperature falls, it produces an explosion of steam—a phenomenon similar to that produced by a drop of water thrown upon a hot metallic cup. If potassium be plunged under water, a violent reaction takes place, potassa alone is formed, and hydrogen gas escapes. Owing to its affinity for oxygen, potassium should be preserved under the surface of a liquid, which contains no oxygen, as naphtha.

145. *Potassa.*—Potassa is the oxide of potassium. It is prepared in the *anhydrous* state, in the form of a white powder, by exposing thin slices of potassium to dry air. When potassium is put into water, a *hydrate* is formed, commonly called, from its energetic action upon the animal textures, *caustic potash*. This substance has a strong affinity for oxygen, and is employed for depriving gases of hygrometric moisture, and for forming freezing mixtures.

146. *Nitre.*—Nitre, or *salt-petre*, is the nitrate of potassa. It is generated spontaneously in the soil, and crystallizes on the surface, in several parts of the world. It is prepared, in some parts of the continent, in artificial nitre-beds, in which nitrate of lime is first formed, and then converted into nitrate of potassa by adding wood-ashes to the ley. Nitre

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144. What are the properties of potassium? What is the effect of potassium upon water? To what is this effect owing? How must potassium be preserved?—145. What is potassa? How is it prepared in an anhydrous, and how in a hydrated state? What is caustic potash? What are its principal uses?—146. What is nitre? In what state is it found in nature? How is it prepared artificially? What are its principal uses? What is sal-prunelle? What is the composition of gunpowder? What is the active ingredient in this compound?

crystallizes readily in long six-sided prisms; it fuses by a heat under redness, and is then poured into moulds, forming *sal-prunelle.* Nitre is chiefly used in chemistry as an oxidizing agent, and in the formation of nitric acid. In the arts, it is much used for making deflagrating mixtures: *gunpowder*, for instance, is a mixture of about one equivalent of nitre, one of sulphur, and three of carbon. In this and all other deflagrating mixtures containing this salt, the oxygen of the nitre is the active ingredient in promoting the rapid combustion of the inflammable matter.

147. *Potashes; Pearl-ash; Salt of Tartar, &c.*—These are carbonates of potassa. 1. Potassa exists in combination with clay and other minerals, which form the earthy part of soil; it appears to be essential to vegetation, being found in the sap of plants, in combination with vegetable acids. Hence, when land plants are dried and burned, their ashes lixiviated, and the solution evaporated to dryness, the salts of the vegetable acids are found to have been destroyed, and carbonate of potassa, commonly called *potashes*, remains. 2. The potashes of commerce, when partially purified by solution, evaporation, and heating in a furnace, constitute the *pearl-ash* of commerce. 3. A very pure carbonate is formed by burning together two parts of *cream of tartar* (bitartrate of potassa), and one of nitre. In this process the tartaric acid of the cream of tartar is completely decomposed, and carbonate of potassa remains mixed with charcoal, from which it may be separated by solution and filtration. The pure carbonate is called *Salt of Tartar.* 4. *White* and *Black Flux* are carbonates of potassa, and are employed in the reduction of metals (p. 83).

148. *Tartar; Cream of Tartar.*—These are bitartrates of potassa. They are found encrusted on the sides and bottoms of wine casks, where, owing to their insolubility in alcohol, they have been deposited from the juice of the grape.

149. SODIUM.—Potassium is the alkaline metal of the vegetable kingdom; *sodium*, or *natrium*, is its analogue in the animal kingdom, its salts being found in all animal fluids. Sodium is very lustrous, and has the aspect of silver. At common temperatures it is so soft that it may be cut with a knife, and yields to pressure of the fingers.

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147. Explain the composition and mode of preparing potashes, pearl-ash, and salt of tartar.—148. What is the composition of tartar, and of cream of tartar? —149. From what sources is sodium procured? What are its properties? How is it distinguished from potassium?

At 194° it is perfectly liquid. It tarnishes on exposure to the air, though its oxidation is less rapid than that of potassium; when heated nearly to redness, it takes fire and burns with a yellow flame. Thrown on cold water, it swims on the surface, and undergoes rapid oxidation, but without taking fire like potassium. If a few drops only of water are applied to sodium, it readily becomes hot enough to take fire. In each case, *soda* is formed, and the water acquires alkaline properties.

150. *Soda.*—Soda, or *natron*, is the oxide of sodium, and is formed when this metal is exposed to the air or to water. When combined with water as a hydrate, it is the *caustic soda* of chemists. Soda is readily distinguished from potassa and other alkaline bases by the following characters:—1. It forms with sulphuric acid a salt well known as *Glàuber's salt.* 2. All its salts are soluble in water, and cannot be precipitated by a re-agent. 3. Its salts impart a rich yellow colour to flame.

151. *Sea salt; common salt.*—Sodium burns in chlorine, and forms a chloride of sodium, or common culinary salt. The different kinds of common salt are procured from the mineral *rock-salt*, or by evaporating sea-water. Sea-water contains 2·7 per cent. of chloride of sodium, which is the most considerable of its saline ingredients. In places on the coast where spontaneous evaporation proceeds rapidly, sea-water is retained in shallow basons or canals, on the surface of which a saline incrustation forms with the progress of evaporation, and is afterwards broken and raked out. On evaporating a solution of salt in water rapidly, it crystallizes in hollow, four-sided pyramids; but it occurs in regular cubic crystals, when the solution is allowed to evaporate spontaneously. The glazing of pottery is effected by decomposition of chloride of sodium: a quantity of this substance is thrown into the kiln, where it is converted into vapour by the heat, and condensing upon the surface of the pottery, causes its vitrification.

152. Lithium.—*Lithium* is a white metal, resembling sodium, and of highly oxidable quality. *Lithia* is the prot-

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150. What is soda? What is caustic soda? State the characters by which soda is distinguished from potassa.—151. What is the composition, and chemical name, of common sea-salt? How is it procured? In what crystalline forms may it be obtained? By what process is the glazing of pottery effected?—152. What is lithium? What is lithia? In what respect does lithia differ from potassa and soda?

oxide of lithium, and it occurs in small quantities in certain minerals; it possesses all the properties of an alkali, and differs from potassa and soda in the very sparing solubility of some of its salts. Lithia has been hitherto obtained only in small quantity.

DIV. II. METALLIC BASES OF THE ALKALINE EARTHS.

153. The Alkaline Earths, baryta, strontia, lime, and magnesia, are oxides of peculiar metals, termed *barium*, *strontium*, *calcium*, and *magnesium*. These are called, from this property, *alkaline terrigenous metals*. Of the alkaline earths, the first three corrode animal and vegetable substances, in the same manner as the alkalies; the fourth does not possess this caustic property. They all, like the alkalies, neutralize acids, and turn the blue infusion of cabbage to green, and turmeric to brown.

154. Barium.—*Barium* was procured by Davy, by means of Galvanism, from the carbonate of baryta. It is a white metal, like silver. It has a strong affinity for oxygen, with which it combines, forming a white powder; it oxidates rapidly in water, and effervesces from disengagement of hydrogen; in both cases, baryta is formed. *Baryta*, or barytes, has a strong affinity for water, and slakes in this liquid, like quicklime, with the evolution of intense heat. The result of this process is a *hydrate of baryta*, a substance which forms an excellent *test* of the presence of *carbonic acid* in the air or other gaseous mixtures: the carbonic acid unites with the baryta, and forms a white insoluble precipitate, the carbonate of baryta. A solution of the carbonate is called *baryta water*.

155. Strontium.—*Strontium* was procured by Davy from strontia, by means of Galvanism. It much resembles barium. It is a dense white metal, oxidizing rapidly in the air, and decomposing water with the evolution of hydrogen. *Strontia* is to baryta, what soda is to potassa. Pure strontia slakes, when mixed with water, with the evolution of intense heat, and forms a white solid hydrate. The salts of strontia communicate a deep red tint to inflammable matter in a

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153. What are the names of the alkaline earths? What is their composition? What are their properties?—154. How was barium first procured? What is baryta? Of what is it a valuable test?—155. How was strontium pro- What is strontia? How are its salts distinguished from those of

state of combustion, by which they are readily distinguished from the salts of baryta.

156. CALCIUM.—*Calcium* was procured by Davy from lime, by means of Galvanism. It has a whiter appearance than barium or strontium. *Lime*, or *quicklime*, is procured by expelling carbonic acid, by means of heat, from the carbonates of lime, as limestone, marble, chalk, or calcareous spar; it is prepared, on the large scale, by placing alternate layers of limestone and fuel in a furnace, or limekiln. Lime is a brittle, white, earthy substance, beautifully phosphorescent when heated to redness, and highly infusible. It combines with water, with the evolution of great heat, and passes into the state of *slaked lime.* The most delicate *test* of lime is oxalic acid, which forms an insoluble compound with it.

157. *Bleaching Powder.*—This is a *chloride*, commonly called *oxymuriate of lime.* On exposing thin strata of recently slaked lime in powder to chlorine, this gas is absorbed in large quantity, and chloride is formed in the state of white powder, which destroys vegetable and animal colouring matters, in the same way as chlorine.

158. *Gypsum, &c.*—Gypsum is a sulphate of lime, occurring abundantly as a natural production. A white compact variety of gypsum is employed in statuary under the name of *Alabaster;* this is a pure crystallized specimen. The salt is deprived of its water at a low heat, and in this state constitutes *Plaster of Paris.* Its property of becoming hard after being made into a paste with water, is owing to the anhydrous sulphate combining chemically with this liquid, and thus depriving it of its fluidity.

159. *Bone Earth.*—This is a phosphate of lime constituting the basis of *bone*, from which it is prepared by burning off the animal matter (p. 56).

160. MAGNESIUM.—*Magnesium* was procured by Davy from magnesia, by means of Galvanism. It is prepared by decomposing its *chloride* by means of potassium. It is a white metal, resembling silver, very malleable, fusing at a red heat, and then burning with brilliancy in air or oxygen

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156. From what substance was calcium procured? How is lime prepared? What is slaked lime? What is the best test of the presence of lime?—157. What is bleaching powder? What is its property?—158. Explain the differences between common gypsum, alabaster, and plaster of Paris.—159. What is bone earth?—160. How is magnesium procured? What is magnesia? What is Epsom salt?

gas, with the formation of magnesia. It takes fire spontaneously in chlorine gas. *Magnesia* is a white earthy powder, procured from the carbonate, by expelling its carbonic acid by heat. *Epsom Salt* is a sulphate of magnesia. It is frequently found in mineral springs. In commerce, it is prepared by the action of sulphuric acid on *magnesian limestone*, a mineral consisting of carbonate of lime and magnesia.

DIV. III. METALLIC BASES OF THE EARTHS.

161. There are *six* metals which combine with oxygen, forming oxides which are well known as the pure *earths;* hence, they are called *terrigenous metals*. The earths are white, insoluble in water, and do not affect the colour of litmus, or turmeric paper. As salifiable bases, they are inferior to the alkaline earths.

162. Aluminium.—*Aluminium* is prepared, like magnesium, by decomposing its *chloride* by means of potassium. The metal is obtained in the form of minute scales or spangles; its appearance is that of a grey powder, resembling spongy platinum. Aluminium fuses at a higher temperature than that at which cast iron melts. Heated to redness in the open air, it takes fire and burns with a brilliant light; sprinkled in powder on the flame of a candle, it emits brilliant sparks, similar to those emitted during the combustion of iron in oxygen gas. The earth, *alumina*, is the only known compound of aluminium and oxygen. It is one of the most abundant productions in nature; it occurs, almost in a state of purity, in the *ruby* and the *sapphire*. Pure alumina is prepared from *alum;* when mixed with water, it yields a soft cohesive mass, which is moulded into various forms, in the manufacture of pottery.

163. *Alum.*—Alum is the *double sulphate of alumina and potassa;* it crystallizes readily, in the form of octohedrons, from a solution containing its elements. It is prepared in this country from a siliceous clay, called *alum-slate;* and in Italy from *alum-stone*, which is produced in volcanic districts by the action of sulphurous acid vapours on felspatic rocks. When this mineral is treated with a due quantity of sulphuric acid, it dissolves, and is converted into the crys-

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161. What are the pure earths called, and why so?—162. How is aluminium prepared? What is alumina? In what precious stones does it occur in a pure state?—163. What is alum? For what purposes is it employed?

tallizable alum of commerce. When the crystals of alum are exposed to heat, they froth up remarkably, and part with all their water, forming anhydrous alum, the *alumen ustum* of the pharmacopœia. Alum is extensively employed in the arts, particularly in dyeing, lake-making, dressing sheepskins, pasting paper, clarifying liquors, &c.

164. *Homberg's Pyrophorus.*—A spontaneously inflammable mixture has been long known under this name. It is made by intimately mixing three parts of alum and one of sugar; the mixture is evaporated to dryness, and then introduced into a small stoneware bottle, which is placed in a crucible, and surrounded with sand. The whole is heated to redness till a blue flame appears at the mouth of the bottle, which is closed after a few minutes by a stopper of chalk. After cooling, the bottle is found to contain a black powder, which becomes red hot when exposed to the air, and takes fire with brilliant combustion in oxygen gas. A similar mixture may be made with three parts of lamp-black, four of burnt alum, and eight of carbonate of potassa.

165. THORIUM, GLUCINIUM, ZIRCONIUM, YTTRIUM, SILICIUM.—These are the metallic bases of the earths *thorina*, *glucina*, *zirconia*, *yttria*, and *silica*. The four first are rarely met with, and require no further description. The last has already been described among the non-metallic bodies.

DIV. IV. METALS WHICH DECOMPOSE WATER AT A RED HEAT.

166. The remaining metals are all capable of combining with oxygen, but their *oxides* are neither alkalies nor earths. Their protoxides have an earthy appearance, but are generally coloured. They are insoluble in water, and in general do not affect the colour of test paper. Most of them are capable of combining with acids, and of forming salts; but in this property they are much inferior to the alkalies and alkaline earths by which they may be separated from their combinations. Several of these metals combine with oxygen, and form compounds with *acid* characters. The first division of this order comprises *seven metals which decompose water at a red heat.*

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164. What is Homberg's pyrophorus?—166. Enumerate the metals which decompose water at a red heat? What are their properties?

167. Manganese.—Manganese is a hard brittle metal, of a greyish-white appearance, and granular texture; it much resembles cast iron in appearance. This element is found in the ashes of plants, in the bones of animals, and in many minerals. It oxidates readily in the air, and falls down as a black powder. It decomposes water at common temperatures, with the disengagement of hydrogen gas; at a red heat, the decomposition is rapid, and protoxide of manganese is formed. It is best preserved in naphtha, or over mercury. Manganese has never been found in an uncombined state, but its *oxides* are very abundant. These are extensively employed, and for opposite purposes, in the manufacture of glass: the *deutoxide* is used for colouring glass of a red or violet colour; while the *peroxide* is used for preserving glass colourless by its oxidating action.

168. Zinc.—Zinc, or *spelter*, is a bluish-white metal, with a bright metallic lustre, and crystalline structure. It is procured from the native carbonate or *calamine*, or from the native sulphuret, called *zinc blende*. At low or high degrees of temperature, zinc is brittle; but between 210° and 300° F., it is both malleable and ductile, and may be rolled or hammered into thin sheets; if *pure*, it is malleable at common temperatures. At 773°, it fuses; when cooled, it crystallizes in four or six-sided prisms. At a red heat, it rises into vapour, and takes fire in the air, burning with a white flame like that of phosphorus; the product of the combustion, when cold, is the *oxide* of zinc,—a white powder, resembling flocks, and called *flowers of zinc;* from its great lightness, it was formerly called *philosophical wool* and *white nothing*. Zinc in the laminated form, is a very valuable substance, owing to its little disposition to undergo oxidation. *White vitriol* is the *sulphate of zinc*, and is formed by roasting the native sulphuret, or by dissolving metallic zinc in dilute sulphuric acid. It crystallizes, on evaporation, in colourless prisms. Zinc unites with copper in several proportions, forming important *alloys*. The best *brass* consists of four parts of copper to one of zinc. When the zinc is in greater proportion, compounds are formed which are called *tombac*, *Dutch-gold*, and *pinchbeck*. The

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167. In what substances is manganese found? For what purposes are its oxides employed?—168. What are the properties of zinc? What is the flowers of zinc? What is white vitriol? What is the composition of brass?

white copper of the Chinese is said to be an alloy of copper, zinc, nickel, and iron.

169. Iron.—Iron is found occasionally in the metallic state, but most commonly mineralized in various ways. It exists in minute quantities in almost all vegetable and animal products, particularly in the blood. Masses of *meteoric* iron, termed *aerolites*, have been found of every size, from that of a few grains to that of several hundreds of pounds in weight. These masses invariably contain iron, cobalt, or nickel, or a combination of these three metals in union with various earthy substances. Iron is of a peculiar grey colour, and admits of a high polish. It is remarkably malleable, and exceeds all the metals in tenacity. At common temperatures it is very hard, and its hardness may be increased by its being heated, and suddenly cooled; but at the same time it becomes brittle. When heated to redness, it is remarkably soft and pliable, and may be beaten into any form, or intimately united, or *welded*, by hammering, with another portion of red-hot iron. In its pure state, iron is exceedingly infusible: the point of fusion of cast iron is 3479°. Iron expands as it returns to the solid state, and therefore takes the impression of a mould with accuracy. It is attracted by the magnet, and may itself be rendered permanently magnetic. This important property is possessed by no other metal excepting cobalt and nickel.

170. *Preparation o Iron.*—Iron is principally procured from the ore called *clay iron-stone*, which, in the process of *reduction*, is first roasted, and then heated with charcoal, coke, or coal, and lime, in a *blast furnace*. The air is thrown in at two or more openings near the bottom, from a blowing apparatus, so as to maintain the whole contents of the furnace in a state of intense ignition. In the process, as thus conducted, the carbon removes the oxygen from the

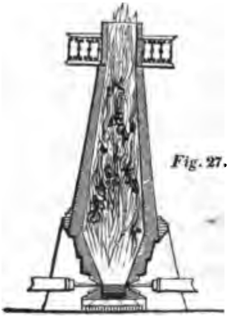

Fig. 27.

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169. How does iron occur in nature? What are aerolites, and what is their composition? What are the properties of iron? What other metals are capable of being rendered magnetic?

iron, forming carbonic oxide or carbonic acid, which escapes. The lime acts the part of a *flux*, by combining with the earthy matter of the ore, and forming a fusible compound, called a *slag*, through which the melted iron falls, and collects at the bottom of the furnace. The slag is let off from time to time at an aperture in the side of the furnace, and the fused iron is carried off by a hole in the bottom of the furnace, received into channels formed in sand, and thus *cast* into ingots or pigs, commonly called *pig-iron.*

171. *Steel.*—Steel is a carburet of iron. The general method of forming steel is by the process of *cementation.* This consists in placing alternate layers of bars of malleable iron, and of powdered charcoal, in a large furnace, from which the atmospheric air is entirely excluded, and keeping the whole for several days at a red heat. By this means the iron gradually combines with from 1-3^{d} to 1·75th per cent. of *carbon;* and the different degrees of temperature to which it is subjected, occasion the varieties in its state of cohesion, or *temper*, which are adapted for making different instruments.

172. *Green Vitriol.*—Green Vitriol, or *Copperas*, is a sulphate of iron, and is prepared by the action of dilute sulphuric acid on metallic iron, or by oxygenation of the native sulphuret, or *iron pyrites*, by the action of air and moisture. This salt is employed in the manufacture of fuming sulphuric acid; in the preparation of ink and Prussian blue; in dyeing black, &c.

173. Tin.—Tin, or *Stannum*, is no where found in the metallic state, but occurs usually in combination with oxygen. It is confined to a few localities, one of the principal of which is Cornwall. The only important ore of tin is the peroxide, which occurs in veins, and also in the form of rounded grains, commonly called *stream tin*, from its having been carried away from its original position by the action of water. Tin has a white, silvery lustre; its brilliancy is very slowly impaired by exposure to air, and is scarcely at all affected by moisture; hence its great value for culinary vessels. Tin is very soft, and exceedingly malleable, the thickness of tin foil being no more than 1-1000th of an inch.

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170. Explain the process by which iron is procured from its ore. What is pig-iron?—171. What is steel? How is it prepared?—172. What is green vitriol? For what purposes is it employed?—173. From what sources is tin obtained? What are its properties? What is *moiree metallique?*

In ductility and tenacity, it is inferior to several of the metals; at the temperature of boiling water, it may be drawn into wire, which is soft and flexible, but deficient in tenacity. At 442°, tin fuses, and if exposed in that state to the air, it tarnishes, and its surface becomes covered with a grey powder. When heated to whiteness, it takes fire, burns with a white flame, and is converted into peroxide of tin. When tin-plate is heated and washed with a liquid, consisting of water, nitric and muriatic acids, the surface becomes crystallized, and in this state it constitutes the *moiree metallique;* this, when varnished, is worked into ornamented vessels.

174. *Mosaic Gold.*—Mosaic Gold, or the *aurum musivum* of the alchemists, is the bisulphuret of tin. It is prepared by igniting a mixture of peroxide of tin, sulphur, and sal ammoniac, in a covered crucible. The product is obtained in the form of crystalline scales, of a golden yellow colour, and metallic lustre.

175. *Alloys of Tin.*—Tin alloyed with small quantities of antimony, copper, and bismuth, forms the best kind of *pewter*. Tin and lead unite when fused together, constituting solder; *fine solder* consists of two parts of tin and one of lead, and is employed in tinning copper; *coarse solder* contains 1-4th of tin, and is used for soldering by glaziers. *Hard solder*, by means of which two surfaces of copper are *brazed*, or cemented together, is an alloy of brass and zinc.

176. Cadmium.—Cadmium is a white metal, resembling tin; it is found associated with zinc, and derives its name from *cadmia fossilis*, the common ore from which the latter metal is obtained. During the reduction of the ores of zinc, cadmium passes over among the first products of distillation, owing to its great volatility, which is nearly as great as that of mercury. Cadmium is very ductile and malleable.

177. Cobalt.—Cobalt occurs principally in combination with arsenic; it is likewise found in almost all meteoric stones. Its name is derived from *Kobold*, the demon of mines, which was applied to it by the German miners, who considered it unfavourable to the presence of valuable metals. Cobalt is a brittle metal, of a reddish-grey colour;

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174. What is mosaic gold?—175. Explain the composition of the alloys of tin.—176. From what source is cadmium derived?—177. In what state does cobalt occur in nature? What is the origin of the term? For what purpose are its ores employed?

it is capable of being rendered permanently magnetic. The ores of cobalt are much used for the *blue* colours of porcelain and stoneware.

178. **Nickel.**—Nickel occurs, together with iron and cobalt, in meteoric stones. It may be prepared from a mineral of Westphalia, termed *Copper-nickel;* or from an artificial production called *speiss*, which is obtained during the reduction of the ores of cobalt. Nickel is a metal of a silvery white appearance, and is both ductile and malleable. It is attracted by the magnet, and, like iron and cobalt, may be rendered magnetic. A mixture of copper, zinc, and nickel, fused together, constitutes the useful white *alloy* of nickel, called German silver, or *packfong*.

DIV. V. OF THE METALS WHICH DO NOT DECOMPOSE WATER AT ANY TEMPERATURE, AND THE OXIDES OF WHICH ARE NOT REDUCED TO THE METALLIC STATE BY THE SOLE ACTION OF HEAT.

179. The above description comprises the history of *ourteen* metals, several of which are of very rare occurrence. They all combine with oxygen, &c., and form compounds possessing many of the characters of *acids*.

180. **Arsenic.**—Arsenic generally occurs in combination with other metals, especially iron and cobalt. A *reverberatory furnace* is employed in the reduction of arsenic from its ores. It consists of a fire-place, *a*, in which the fuel is burned, and of which *b* is the ash-pit; *d d* is a horizontal flue, expanded into a small chamber or oven, which is raised to a strong red heat by the *reverberation* on its walls of the flame, or heated air, from the fire on its passage to the chimney. The matters to be heated are

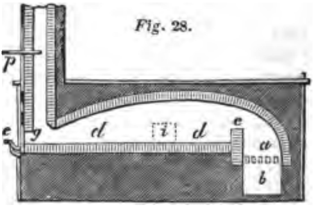

Fig. 28.

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178. How does nickel occur in nature? What is speiss? What is packfong? —180. Explain the process for the reduction of arsenic. What are the properties of arsenic? What is fly-powder?

placed on the floor of the chamber. There is an opening in the side at *i*, for the introduction of materials, and another opening, *g*, at the end most distant from the fire. The chimney is provided with a damper, *p*, by which the draught is regulated. On roasting the arsenical ores in a furnace of this kind, the arsenic, which is very volatile, is driven off, combines with oxygen as it rises, and condenses into thick cakes, on the roof of the chimney; this mass, when sublimed a second time, constitutes the virulent poison, commonly called *arsenic;* it is, however, *arsenious acid*, or the *white oxide of arsenic.* To obtain metallic arsenic, one part of the white oxide is mixed with three parts of black flux, and the mixture exposed to red heat in a crucible, over which is luted an empty crucible for receiving the metal, and which is kept cool for the purpose of condensing the vapour of the metal as it rises. Arsenic is a brittle metal, of a strong metallic lustre, and steel-grey colour. It crystallizes by sublimation in rhombohedrons. At 356° it sublimes without liquefying; it fuses at a higher temperature, but this has not been ascertained. Its vapour has a strong garlicky odour. Arsenic tarnishes on exposure to the air, forming a grey oxide, called *fly-powder.*

181. CHROMIUM.—*Chromium* is prepared, by a difficult process, from the mineral called *chrome iron.* It is a greyish-white metal, brittle, and very infusible. The *oxide of chromium* is of a *green* colour, and, when fused with borax or other vitreous substances, it communicates to them a beautiful green colour, a property which affords an excellent test of its presence, and renders it exceedingly useful in enamelling, and in glass and porcelain painting. The emerald owes its colour to the presence of this oxide. Oxide of chromium is also the colouring matter of *pink*, applied to stoneware. *Chrome yellow* is the chromate of lead; it furnishes to the painter his best and most lively yellow. *Chrome red* is the bichromate of potassa.

182. VANADIUM, MOLYBDENUM, TUNGSTEN, COLUMBIUM.—These metals are of very rare occurrence, and are with great difficulty reduced to the metallic state from their ores. They are but imperfectly known, and have not been applied to any useful purpose.

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181. What is chromium? For what purpose is its oxide employed?

183. **Antimony.**—Antimony, said to have derived its name, *anti-moine*, from its fatal effects upon some monks to whom it was given as a medicine, sometimes occurs native, but is generally procured from its sulphuret. This ore, formerly called *stibium*, was long regarded as the metal itself, and was termed antimony, or *crude antimony*, while the pure metal was termed *regulus of antimony*. On heating the sulphuret of antimony in a crucible with half its weight of iron filings, sulphuret of iron is formed, and metallic antimony is separated. Antimony is a white, brittle metal, of considerable lustre. At 797° it fuses, and, on cooling, acquires a highly lamellated texture, and sometimes yields crystals. It burns in air at a red heat, with the production of copious fumes, which condense on cool surfaces, frequently in the form of small shining needles of silvery whiteness, formerly called *argentine flowers of antimony;* they are the oxide of antimony.

184. **Bismuth**—Bismuth, or wismuth, so named by the Germans, or *tin glass*, as it is called by artists, occurs native and in combination with other substances. For chemical purposes, the metal is procured from the subnitrate, commonly called *magistery of bismuth*, a beautifully white substance, sometimes employed as a paint for improving the complexion; it is, however, an inconvenient cosmetic, owing to the facility with which it is blackened by sulphureted hydrogen. Bismuth is a white metal with a reddish shade, and highly crystallizable. It is brittle when cold, but malleable when warm. It is volatile at a full red heat, and burns in air at a high temperature with a pale-blue flame, and with the formation of copious fumes of oxide of bismuth; the product of the combustion is a yellow powder, called *flowers of bismuth*. The chloride, formerly called *butter of bismuth*, is formed by throwing finely pulverized bismuth into chlorine gas. The *alloys* of bismuth are remarkable for their fusibility; the best proportion consists of eight parts of bismuth, five of lead, and three of tin. Equal parts of bismuth, tin, and mercury, form the *mosaic gold*, used for various ornamental purposes. One part of bismuth, with five of lead, and three of tin,

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183. What are the properties of antimony? Explain the terms *crude antimony*, and *regulus of antimony?*—184. From what source is bismuth procured? What are its properties? Explain the composition of some of the alloys of bismuth.

forms *plumber's solder*, a compound of great importance in the arts. Bismuth is also added to the alloy of tin and lead used for casting stereotype plates; besides increased fusibility, bismuth communicates to this alloy the property of expanding on becoming solid, so as to admit of a clear and sharp impression of the type. Bismuth is found associated with sulphur, constituting the mineral *bismuth glance.*

185. URANIUM, CERIUM, TITANIUM, TELLURIUM.—These metals are of very rare occurrence, and their properties are very imperfectly known. They have not been applied to any useful purpose.

186. COPPER.—Copper is one of the most abundant of the metals. It is prepared principally from the ore called *copper pyrites*, the native sulphuret of copper and iron. The ore is first roasted, by which means part of the sulphur is expelled; the residue is then roasted with siliceous matter, and the iron is converted into a fusible slag; by continued roasting, most of the sulphur escapes as sulphurous acid, and the copper is oxidized; after which, it is reduced by charcoal and by directing a strong blast of air upon the surface of the melted copper. Copper is a hard, elastic, sonorous metal; it is the only metal, with the exception of titanium, of a *red* colour; it is both ductile and malleable, and in tenacity yields only to iron; it is less fusible than silver, and more so than gold; its point of fusion being 1996° F. Copper is little affected by dry air, but in a damp atmosphere it becomes coated with a green crust, which is subcarbonate of copper. Copper unites with oxygen, forming the *red* and the *black oxide.*

187. *Blue Vitriol, and Verdigris.*—1. Blue vitriol is the *sulphate of the black oxide of copper*, and may be prepared by dissolving the oxide in dilute sulphuric acid, or by oxygenating the sulphuret by the action of heat and air. 2. Verdigris, commonly used as a pigment, is an *acetate of copper*, and is prepared by covering copper-plates with cloth soaked in pyroligneous acid.

188. *Alloys of Copper.*—The most important of the alloys of copper are those formed with tin and zinc. *Bronze* and *Gun Metal* consists of 100 parts of copper, and 10 of tin; *Bell Metal*, of 100 parts of copper, and 20 to 25 of tin;

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186. From what substance is copper principally procured? What are its properties?—187. What is blue vitriol? What is verdigris?—188. State the composition of bronze, of bell-metal, of speculum metal, and of brass.

Speculum Metal, of 100 parts of copper, and 30 to 35 of tin; a little arsenic is added to the last alloy, to increase its whiteness. The varieties of *Brass* are alloys of copper and zinc; four parts of copper and one of zinc form a golden-coloured alloy, hence called *Similor*.

189. LEAD.—Lead is procured principally from *galena*, the native sulphuret of this metal. This ore, in the state of a coarse powder, is heated in a reverberatory furnace (p. 96), together with coal and lime, the latter of which assists in removing the sulphur, and any sulphurous or sulphuric acid formed during the process. Lead is of a bluish-grey colour, and metallic lustre, but it soon tarnishes on exposure to the air. It is both malleable and ductile; in tenacity, it is inferior to all ductile metals. It melts at 612°; on solidifying, it shrinks considerably, so that bullets cast in a mould are never perfectly round. Lead is precipitated slowly in the form of crystals, forming the *lead tree*, when zinc is introduced into any of its solutions. Air and water charged with carbonic and other acids, oxidate lead; hence, rain or soft water cannot be safely preserved in leaden cisterns, owing to the rapid formation of a white hydrated oxide at the line where the metal is exposed to the air and water; this oxide is soluble in pure water, and is highly poisonous. It is found, however, that certain substances exert a *protecting influence* on water thus preserved, by arresting the oxidation of the lead. Thus, if a minute trace of any sulphate or chloride exist in the water, as is usually the case with spring or well water, the corrosion of the lead is arrested by conversion of the oxide of lead into an insoluble salt, and the water is preserved from contamination. In these cases, the preservative power of neutral salts is closely connected with the *insolubility* of the compound which their acid is capable of forming with lead. The water of Edinburgh is a remarkable illustration of this rule.

190. *Massicot; Litharge; Minium.*—On exposing melted lead to the air, the surface becomes rapidly covered with a film, which acquires a yellow colour; when skimmed off in this state, it is termed *massicot*, or *yellow lead*, and was

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189. How is lead prepared? What are its properties? Why cannot rain or soft water be safely preserved in leaden vessels? What substances exert a protecting influence on water thus preserved? Upon what circumstance does this ing influence depend?—190. Explain the formation of massicot, of nd of minium.

formerly used as a yellow pigment; this is the protoxide of lead. Massicot, when imperfectly fused, forms a red mass, which separates into small crystalline scales, called *litharge*, or semi-vitrified oxide of lead. When massicot, which has not been fused, is exposed to incipient redness, and a current of air directed upon its surface, it slowly absorbs oxygen, and is converted into the *red oxide*, or the *minium* of commerce, a substance employed as a pigment, and in the manufacture of flint glass. This is the deutoxide of lead.

191. *White Lead*, or *Ceruse*.—This compound, employed as a white pigment by painters, is the *carbonate of lead*. It is prepared by placing thin sheets of lead over pots containing weak acetic acid, and exposed to a gentle heat by being imbedded in fermenting tan. By the vapour of the acid the lead is corroded, and at the same time oxidated, and its external portions come off in flakes, which are carbonate of protoxide of lead. The oxygen is derived from the air, and the carbonic acid from the fermenting tan.

192. *Alloys of Lead.*—Lead and tin fuse together, and form an alloy called solder. *Fine Solder* is an alloy of 2 parts of tin and 1 of lead, and is much employed in tinning copper. *Coarse Solder* contains 1-4th of tin, and is employed for soldering by plumbers. The other alloys of lead have been already noticed under the articles Tin and Antimony.

DIV. VI. OF THE METALS, THE OXIDES OF WHICH ARE DECOMPOSED BY A RED HEAT.

193. The above description comprises the history of *eight* metals. The first of these occurs in a *liquid* state. The two next are termed *noble metals;* they are remarkable for their beauty, and for the difficulty with which they are acted on by heat, and other agents. The fourth is the *heaviest* body in nature, and is with difficulty acted upon by most ordinary agents. The remaining four occur in very minute quantities, and their properties are therefore very imperfectly known.

194. Mercury.—Mercury, or Quicksilver, is found, to a

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191. What is white lead? How is it prepared?—192. State the composition of fine, and of coarse solder.—193. Enumerate the metals, the oxides of which are decomposed by a red heat.—194. In what state does mercury occur in nature? What are its properties? What is red precipitate?

small extent, in the metallic state; but it occurs more abundantly in the ore *cinnabar*, in which it exists in combination with sulphur. On heating this ore with lime or iron filings, the mercury is volatilized, and the sulphur remains; the mercury is then freed from impurities by distillation with half its weight of iron filings. Mercury is *fluid* at common temperatures; it has a tin-white colour, and a high metallic lustre. At 39 or 40 degrees below zero, it becomes solid, and crystallizes in octohedrons; it contracts considerably at the moment of congelation. At 662° it boils, forming a colourless vapour, and condenses again on cool surfaces into metallic globules. Mercury combines with oxygen, forming the *black*, and the *red oxide;* the latter is commonly called *red precipitate.*

195. *Cinnabar; Vermilion, &c.*—1. The common ore of mercury, *Cinnabar*, is a sulphuret; it sometimes occurs crystallized, forming a beautiful vermilion. 2. A sulphuret, called *factitious cinnabar*, is formed by fusing sulphur with about six times its weight of mercury, and subliming in close vessels. The red pigment, *vermilion*, consists of the factitious cinnabar reduced to powder. This sulphuret is black before sublimation. 3. When equal parts of sulphur and mercury are triturated together until metallic globules cease to be visible, a dark-coloured mass is formed, called *ethiops mineral.*

196. SILVER.—Silver occurs native in mines, and in combination with several metals; in the state of sulphuret, it is frequently associated with *galena*. Silver has a brilliant white appearance, and admits of the highest polish. It melts at a bright-red heat, absorbing oxygen when pure, and expelling it again as it cools. It is extremely ductile and malleable. Silver is precipitated from its solution in the metallic state by most other metals; when mercury is employed, the silver assumes a beautiful arborescent appearance, called *arbor Dianæ;* the silver thus deposited always contains mercury. Pure silver, being very soft, is always alloyed, in coin and plate, with copper, in order to make it harder. The *standard* silver of this country is an alloy of 222 pennyweights of silver, with 18 pennyweights of copper.

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195. What are cinnabar, and factitious cinnabar? What is vermilion? What is ethiops mineral?—196. In what states is silver found in nature? What are its properties? What is the *arbor Dianæ?* What is the composition of the *standard* silver of this country?

When the proportion of copper is considerable, the coin becomes red by wear.

197. Gold.—Gold generally occurs native, in the massive state disseminated in threads through rocks, or in grains among the sand of rivers; it is also found in combination with other metals. It occurs crystallized in the cube and its allied forms. Gold is separated from silver by the process of *quartation;* this consists in fusing the gold with so much silver that the former metal may constitute *one-fourth* of the mass; nitric acid will then dissolve all the silver and leave the gold. The silver may also be separated by digestion in sulphuric acid. Gold is the only metal of a yellow colour. It is highly malleable and ductile. When very thin, gold is transparent, thin gold leaf allowing a green light to pass through it. Gold fuses at 2016°, and contracts considerably on becoming solid. Gold combines with oxygen in two proportions, forming the *aurous* and the *auric oxides;* the latter combines with ammonia, forming *fulminating gold,* so named from its violently explosive character.

198. Platinum.—Platinum, so named from *plata,* silver, which it resembles in whiteness, is found in the metallic state, associated or combined with various metals; it occurs in the form of rounded or flattened grains. Platinum is the *heaviest* of known metals; it is soft, and, like iron, admits of being welded at a high temperature; it is very malleable and ductile; it is not affected by air or moisture at any temperature; it is infusible in the most powerful furnaces, but melts in the flame of the oxy-hydrogen blowpipe, or by means of Galvanism. Platinum is used in the construction of crucibles, in cases in which acids are employed which would act upon other metals, or upon glass; it is also used in the form of a conducting wire in electric and galvanic batteries. The remarkable property of spongy platinum in causing the union of oxygen and hydrogen gases, has been already noticed, pp. 32, 33.

199. *Aphlogistic Lamp.*—The principle of the Aphlogistic, or *flameless,* lamp depends upon the slow combustion of inflammable or explosive substances at a lower temperature

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197. In what state does gold occur in nature? Explain the process of separating gold from silver by quartation. What are the properties of gold? What is fulminating gold?—198. In what state is platinum found in nature? What are its properties? For what purposes is it used?—199. Explain the principle of the aphlogistic lamp.

than is necessary for inflammation. In the annexed figure, A represents a vessel, which is supplied with alcohol by an aperture at C. A glass tube, B, of several inches in length, is fitted to the vessel by means of a wooden cork. Within the glass tube is a coil of platinum wire, wound round a piece of wood, which tapers upward in a conical form; a communication between the wire and the alcohol is effected by means of a piece of wick. When the lamp is to be used, the platinum may be ignited by the flame of a candle; the wire will remain red hot, and emit a feeble light, so long as there is any alcohol in the vessel. A cylinder of camphor may be substituted for both the wick and the alcohol.

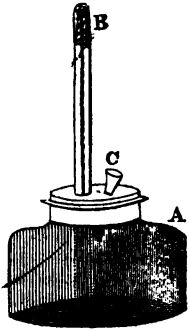

Fig. 29.

200. Palladium, Rhodium, Osmium, Iridium.—These four metals are found in the ore of platinum. When the ore is digested in hydrochloric acid, the platinum, together with palladium, rhodium, and other metals, is dissolved; while a black powder remains, which consists of osmium and iridium. These metals are procured in very small quantities, and their properties are very imperfectly known; they exhibit the same property as platinum, in determining the combustion of oxygen and hydrogen gases.

201. *Experiments.*—(1.) If a portion of *potassium* be heated, and confined in a glass vessel of oxygen, combustion rapidly takes place, with a brilliant white flame, and with the formation of pure potash.

(2.) If a globule of *sodium* be thrown into hot water, the water is violently decomposed, with the production of sparks and flame, as the particles of the metal are thrown out of the water.

(3.) If a little pure *baryta* and a spoonful of alcohol be stirred together in a tea-cup, and inflamed, the mixture will burn with a brilliant yellow colour. If a little powdered *strontia* be similarly treated, it will burn with a splendid red flame.

(4.) Pour some lime-water into a tumbler, and breathe frequently

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200. What other metals are found associated with the ore of platinum? In what do these metals agree with platinum?

into it by means of a glass tube; the liquid, from being transparent will become opaque, owing to the formation of carbonate of *lime* by the union of the carbonic acid from the lungs with the lime of the water.

(5.) If a saturated solution of sulphate of *magnesia* be heated, and mixed with a solution of carbonate of potash, decomposition immediately takes place, and carbonate of magnesia will be precipitated in the form of a light white powder.

(6.) Make a strong solution of *alum*, so that it will crystallize on cooling, and suspend in it a wire basket; on withdrawing the basket in an hour or two, it will be found to be covered with a crust of beautiful crystals. Instead of alum, sulphate of copper, or blue vitriol, may be employed.

(7.) If one part of the black oxide of *manganese*, and three parts of nitrate of potash, be melted in a crucible till no more oxygen gas is disengaged, a greenish powder is obtained, called *mineral chameleon*. Dissolve two or three grains of this in a wine-glass of warm water, and observe the *many* variations of colour as the water cools, produced by the constantly varying temperature.

(8.) If a solution of sulphate of *zinc*, and some liquid ammonia, be mixed together, the zinc will be precipitated in a white mass, and, if the mixture be then shaken, the white mass will be almost immediately re-dissolved.

(9.) The difference between an *iron* and a *steel* instrument may be seen by letting a drop of nitric acid fall on each: a black spot will be formed on the latter, owing to the acid oxidizing the carbon of the steel, and converting it into charcoal; no such effect will be produced on the iron.

(10.) If some powdered nitrate of copper, moistened with a very little water, be spread on a piece of *tin foil*, and wrapped up immediately, the foil will presently ignite, and burst into a flame.

(11.) Write with a solution of muriate of *cobalt*, and the writing, while dry, will not be perceptible; but, if held to the fire, it will gradually become visible, and appear of an elegant green colour. With acetate of cobalt, the writing will be blue.

(12.) If metallic *arsenic* be previously inflamed in oxygen gas, it will burn till the whole is consumed, with a very brilliant combustion.

(13.) If five or six grains of sulphuret of *antimony* be mixed with half its weight of chlorate of potash, and the mixture be smartly struck with a hammer, upon a steel anvil, it fulminates with a loud report, and with the emission of a brilliant and rapid flame.

(14.) A solution of *bismuth* in nitric acid is colourless; a solution of galls is also colourless; pour the solutions together, and a *brown* precipitate will be procured.

(15.) A bright silver coin may be dipped into a solution of sulphate of *copper*, without undergoing change; but if the blade of a penknife, or a piece of polished iron, be immersed in the solution, it will acquire the appearance of copper.

(16.) Mix half an ounce of each of the following salts:—sulphate of magnesia, sulphate of soda, sulphate of copper, and alum—in a large cup of boiling water. Evaporate slowly, and each salt will be found separately crystallized, presenting the same form and properties which it possessed previous to its solution.

(17.) If an ounce of *red-lead* and half a drachm of powdered charcoal be intimately mixed in a mortar, and the mixture be introduced into the bowl of a tobacco pipe, and thus placed in a common fire, the lead will be *reduced*, and may be poured out in the metallic state.

(18.) Fill a small bottle with a solution of acetate of lead; then introduce a small piece of zinc, suspended by a thread to the cork; in a day or two the lead will be precipitated from its solution, and will adhere to the zinc, forming what is called the *lead tree*.

(19.) If *mercury* be heated in chlorine gas, it burns with a pale red flame, and the substance, called *corrosive sublimate*, is formed. This preparation is a bi-chloride of mercury.

(20.) If a bar of polished copper, or a piece of copper wire, be dipped into a solution of nitrate of *silver*, and allowed to remain there for ten minutes, it will be found, on removal, to be coated with metallic silver.

(21.) If a small quantity of the above solution be dropped on a clean plate of copper, a metallie vegetation will soon be perceived, spreading out into various forms, furnishing an instance of metallic reduction.

(22.) The *tree of Diana* is formed by means of an amalgam of *silver* and mercury dissolved in diluted nitric acid, and mixed with water. If an ounce of this solution be poured into a phial, and a small piece of soft amalgam of silver be dropped in, filaments of *reduced silver* will shoot from it, and extend upwards, in the form of a shrub.

(23.) Pour a little purified nitric acid into one wine-glass, and muriatic acid into another, and drop a little *gold-leaf* into each. In this case neither of these corrosive acids will act upon the metal. But, if the contents of the two glasses be poured together, the metal will be completely dissolved.

CHAPTER XIV.

APPLICATIONS OF CHEMICAL SCIENCE.

202. *Application of Chemial Science in Agriculture.*—This subject has been ably investigated by Liebig, whose views are, in many instances, so novel and of such extensive application, as to deserve a special notice. Liebig divides his subject into two parts. In the first, he discusses the chemical processes which occur in the nutrition of vegetables, with particular reference to the chemical compounds which yield them their principal constituents. The second part is devoted to the chemical processes of fermentation, putrefaction, and decay; and to the changes which organic substances undergo in their conversion into inorganic compounds, as well as to the causes which determine these changes.

203. When plants are submitted to destructive analysis, they are found to consist, principally, of carbon, nitrogen, and oxygen and hydrogen in the proper relative proportions for forming water. Hence, the question arises—from what sources are these elements supplied to plants?

204. *Assimilation of Carbon.*—The fertility of every soil has been generally supposed by physiologists to depend on the presence in it of a peculiar substance, called *humus*, or vegetable matter in a state of decay. This substance was supposed to be absorbed by the roots of plants, and thence conveyed into vegetable tissues, where its carbon is abstracted. Yet Liebig adduces the following most conclusive proofs that humus, in the form in which it exists in the soil, does not yield the smallest nourishment to plants. 1. The *humus* or *humic acid* of chemists, although soluble when newly precipitated, becomes completely insoluble when dried in the air, or when exposed in the moist state to the freezing temperature. This is also proved by treating a portion of good mould with cold water: the fluid remains colourless, and is found to have dissolved less than a 100,000th part of its weight of organic matters, and to

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203. What are the constituents of vegetable matter?—204. What opinion was held by physiologists respecting the action of *humus?* State the arguments by which Liebig controverts this opinion.

contain merely the salts which are present in rain-water. 2. Supposing, for the sake of argument, that humic acid is absorbed, in the form of that salt which contains the largest proportion of the acid, viz. of *humate of lime*—it is then shown by Liebig, from the known quantity of the alkaline bases contained in the ashes of plants, in relation to the carbon they contain, that not so much as 1-30th of the carbon of fir-wood, nor so much as 1-20th of the carbon of wheat straw, could be derived from humus in this way. 3. The quantity of humic acid, which plants can receive through the agency of *rain-water*, is next considered. Humate of lime requires 2,500 parts of water for solution. Now, supposing all the rain-water which falls upon a field to become saturated with humate of lime, and to be absorbed by the plants growing upon it, then the quantity of humate of lime, which the plants thus nourished could obtain, might be calculated. But it is proved to be quite insufficient to account for the carbon contained in the corn or in the beet-root grown upon the land. 4. Lastly, a certain quantity of carbon is taken every year from a forest or meadow, in the form of wood or hay, and, in spite of this, the quantity of carbon in the soil increases—it becomes richer in humus.

205. The carbon of plants must, therefore, be derived from other sources; and, as the soil does not yield it, it can only be obtained from the atmosphere. It has been found by experiment that the quantity of carbonic acid in the atmosphere amounts to one-thousandth of its weight; and this amount is sufficient to supply carbon to all the plants and animals on the surface of the earth. "It is known," says Liebig, "that a column of air of 2441 ℔s. weight rests upon every square Hessian foot (= 0·567 square foot English) of the surface of the earth; the diameter of the earth and its superficies are likewise known, so that the weight of the atmosphere can be calculated with the greatest exactness. The thousandth part of this is carbonic acid, which contains upwards of 27 per cent. carbon. By this calculation it can be shown, that the atmosphere contains 3306 billion ℔s. of carbon—a quantity which amounts to more

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205. What is the amount of carbonic acid contained in the atmosphere? How does Liebig show that this amount contains sufficient carbon for the supply of the whole vegetable kingdom?

than the weight of all the plants, and of all the strata of mineral and brown coal, which exist upon the earth. This carbon is, therefore, more than adequate to all the purposes for which it is required."

206. Having shown that the carbon of plants is derived from the atmosphere, Liebig proceeds to inquire what is the actual influence of *humus* on vegetation. Humus, as has already been stated, is vegetable matter in a state of decay, and its decay is accompanied by a phenomenon of a peculiar kind. This substance, in contact with air or oxygen gas, converts the latter into an equal volume of carbonic acid, and its decay ceases upon the disappearance of the oxygen. A substance then remains, *mould*, which is the product of the complete decay of woody fibre, and constitutes the principal part of brown coal and peat. "*Humus*, therefore, *is a continued source of carbonic acid*, which it emits very slowly. An atmosphere of carbonic acid formed at the expense of the oxygen of the air, surrounds every particle of decaying humus. The cultivation of land, by tilling and loosening the soil, causes a free and unobstructed access of air. An atmosphere of carbonic acid is, therefore, contained in every fertile soil, and is the first and most important food for the young plants which grow in it." It is hence concluded that humus nourishes plants, not by being absorbed and assimilated *per se*, but by presenting to their roots, in a decomposing state, a slow and continued source of nourishment, in the form of carbonic acid. This source is beneficial to plants only until their leaves are developed, which enable them to assimilate carbon from the atmosphere.

207. *Assimilation of Hydrogen.*—The solid part of plants, or woody fibre, contains carbon and the constituents of water, or the elements of carbonic acid and a certain quantity of hydrogen: 100 parts of carbonic acid require the addition of 8·04 parts of hydrogen to form woody fibre, and 72·35 parts of oxygen are separated in the state of gas, if we suppose that the hydrogen is derived from the decomposition of water. Water is a remarkable combination of two elements, which have the power to separate themselves from one another, in innumerable processes, in a manner imper-

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206. What, then, is the precise action of *humus* in the nutrition of plants? For how long a period in the life of a plant is the action of humus required?—207. From what source is the *hydrogen* of plants supposed to be derived? Whence is it inferred that plants are capable of decomposing water?

ceptible to our senses; and we may be certain that plants possess this property, from their generating such substances as wax, volatile oils, &c., which are rich in hydrogen, but contain no oxygen; there is, in fact, no other body, but water, from which they could obtain the hydrogen of these matters.

208. *Assimilation of Nitrogen.*—As the carbon and the hydrogen are not presented in their simple state to the absorbing vessels of plants, so it is concluded that nitrogen is not admitted in its uncombined form. Liebig adduces many facts to prove that it is *ammonia*, which affords all vegetables, without exception, the nitrogen which enters into their composition. He has shown that ammonia exists in the atmosphere, a sensible quantity of this substance having been found in rain water collected at a distance from all habitations. The amount of nitrogen exhaled into the atmosphere from thousands and millions of dead bodies is more than sufficient to supply all those living at one time with this element. Liebig also shows that animal manure, so far as regards the assimilation of nitrogen, acts only by the formation of ammonia. The advantage of manuring land with *burned clay*, and the fertility of ferruginous soils, which have been considered incomprehensible facts, are explained in an equally simple manner.

209. The limits of this elementary work forbid the introduction of various other subjects connected with vegetable physiology, as elucidated by chemical science. They are, however, equally interesting with the foregoing; and it is hoped that the young student will not fail to make himself acquainted with the views of Liebig, whose work may justly be considered as the earliest application of the newly-created science of Organic Chemistry to Agriculture.

210. *Application of Chemical Science in Manufactures.*—The manufacture of *Sulphuric Acid*, and the various relations of this substance to other departments of industry, furnish an interesting illustration of the value of chemical science in promoting, not only the physical comforts of individuals, but the commercial welfare of nations at large. The subject has been lately impressed upon the German

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208. From what compound body is the *nitrogen* of plants procured? From what sources is ammonia supplied to the atmosphere? How does animal manure act in the process of vegetable nutrition?

public by an able article in the "Allgemeine Zeitung," and has been laid before the British Government in a "Letter on the State of the Schools of Chemistry in the United Kingdom," by Dr. William Gregory, of Aberdeen. The following observations have been principally compiled from the latter source. The account is given as a specimen of the effects produced by one chemical manufacture only, although that is probably the most important of all, if we except the iron manufacture.

211. The first great stimulus to the improvement of the manufacture of sulphuric acid was given by the announcement of a prize of £40,000, offered by the Emperor Napoleon for the discovery of a simple and cheap process for extracting *soda* from sea-salt. Soda, as is well known, has been used, from time immemorial, for the manufacture of *soap* and *glass*, two products of the highest value to mankind. During the war, France was deprived of her accustomed supply of barilla (the usual source of soda) and of soap from Spain, the ports of both countries being watched by the British fleet. The high price of soda, soap, and glass, consequent on this state of things, led to the offer of the prize above mentioned; and the difficulty was removed by the French chemist, Leblanc; who furnished a cheap and simple process for extracting soda from sea-salt. France soon supplied herself at a cheaper rate than before, and manufactories of soda, soap, and glass, arose and flourished. Let us now consider the nature of Leblanc's process.

212. To convert salt into soda, the first step, according to this process, which is now, with some modifications, uniformly followed, is to convert the salt into *sulphate of soda.* This can only be done by means of sulphuric acid, of which 80 ℔s. are required for 100 ℔s. of salt. Hence, one of the first effects of Leblanc's discovery was, to create a very large demand for sulphuric acid. The attention of scientific men was, henceforth, directed to the economical improvement of this manufacture; every year produced some new amelioration, while the price of the acid steadily fell, and the demand for it as steadily increased.

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211. Explain the cause which led to the improvement of the manufacture of sulphuric acid, in France. For what important purposes is soda employed?—212. What is the first step in Leblanc's process? What substance was immediately brought into great demand?

213. The price of the materials for manufacturing sulphuric acid, viz. sulphur and saltpetre, now became a point of more importance than formerly. That of *nitre* was so high, as to stimulate the manufacturer to search for some substitute, which was speedily found in the *nitrate of soda*, enormous beds of which cover whole plains in South America. This salt is much cheaper than saltpetre, and preferable to it for the manufacture both of nitric acid and of sulphuric acid; but, besides the direct effect of cheapening these acids, the introduction of nitrate of soda, by limiting the use of saltpetre to the making of gunpowder, for which nitrate of soda does not answer, has produced the indirect effect of cheapening gunpowder, the price of saltpetre necessarily falling as the demand for it diminished. This must be, in time, a material source of saving to governments.

214. Finally, with regard to the chief material, *sulphur*, on which the price of sulphuric acid now principally depends, it is well known that our manufacturers derive nearly their whole supply from Sicily, so that Naples may be said to possess a monopoly of that article. That the trade in sulphur is highly important to both nations is obvious, when we reflect on the enormous quantities of sulphuric acid now manufactured in Britain alone. A small manufactory will produce from 250 to 300 tons annually; a large one, 3000 tons, or more; it is no wonder, then, that the late interruption to the trade in sulphur caused great uneasiness among our manufacturers. But it had another effect: the attention of chemists was keenly directed to other means of procuring sulphur, and during the period of obstruction to the sulphur trade, it is said that no fewer than fifteen patents were taken out in England for recovering the sulphur from the sulphuric acid used in the soda manufacture. The restoration of the trade to its accustomed channel has postponed the accomplishment of this object; but the impulse has been given, and Naples may ere long find good cause to regret that she ever allowed any obstruction to the trade in sulphur. We have whole moun-

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213. In the manufacture of sulphuric acid, what substance was employed as a substitute for nitre? What indirect effect was produced by this substitution?—214. Whence is our supply of sulphur obtained? Show the importance of the sulphur trade to both countries. What other sources of sulphur are available to this country?

tains of gypsum and heavy spar, and abundance of pyrites and galena, all of them minerals containing sulphur, which we shall one day find the means of extracting economically; indeed, during the period above alluded to, many tons of sulphuric acid were actually made from iron pyrites. When we consider the resources of modern chemistry, it will not appear improbable, that, if the sulphur trade had been obstructed for a year longer, it might by this time have been lost to Naples for ever.

215. These considerations are of themselves sufficient to show that the manufacture of sulphuric acid has become a matter of national importance, were it only on account of its use in making soda; this alkali is now sold in a state of perfect purity, and at a wonderfully low price, so low, indeed, as almost to have put an end to the use of potash. The quality of glass and soap has been very much improved, and their price greatly diminished; the consumption of both articles has naturally increased in a corresponding ratio. Wood ashes, no longer in demand to nearly the same extent as formerly for manufactures, must also fall in price, and will soon be employed as one of the most powerful manures for our wheat fields.

216. Such are a few of the bearings of the manufacture of sulphuric acid, called into existence, or, at least, vitally improved, by the demand for cheap soda. But this is not all. One or two of its immediate results remain to be pointed out.

217. *Bleaching Powder.*—"It has already been mentioned, that sea-salt, in order to yield soda, must first be converted into sulphate of soda. Now, in acting on the salt for this purpose with sulphuric acid, an enormous quantity of *muriatic acid* is produced, which, in the earlier periods of the manufacture of soda from salt, was thrown away as worthless, so great were the profits realized on the soda. But muriatic acid contains *chlorine*, and no other compound of chlorine yields that body more easily or more cheaply than muriatic acid. The *bleaching* properties of chlorine were known, but had not yet been applied on the great scale. At first the chlorine was disengaged directly from the muriatic acid,

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215. State, generally, the beneficial results which have accrued from the improved manufacture of sulphuric acid.—217. What advantage was secured by Leblanc's process in the production of *bleaching powder?* What would have been the results of continuing the old process of bleaching?

and brought in contact with the cloth to be bleached, in the form of gas; but it was soon found that, by combining the chlorine with lime, it might be obtained in a solid form (bleaching powder), capable of transportation to any distance. Hence arose a new and lucrative manufacture, of such importance, that it may safely be asserted, that, but for the discovery of the bleaching powder, the cotton manufactures of Britain would never have attained their present development: nay, more, had the British manufacturers been tied down to the old method of bleaching, they could not long have competed, in the price of cottons, with France or Germany.

218. "To bleach in the old style, the first requisite is land, and that, good and well-exposed meadow land. The cloth must be exposed for several weeks, and that only *during summer*, to sun and air, and must besides be constantly watered by hand. Now, a single manufactory, of moderate size, near Glasgow, bleaches on the new system, on an average, 1,400 pieces of cloth *daily throughout the year*. Let us only consider what an amount of capital would be required merely to rent the land necessary for bleaching in the old manner this enormous quantity of cloth, in the vicinity of a large city. Let us reflect on the time and labour which would be indispensable, and we shall soon perceive that, with such burdens, the British manufacturer could not compete with his rivals on the continent, where vast tracts of fine meadow land might be had, distant from any great city, at a far cheaper rate, and in a more sunny climate. The superiority of our machinery would thus be in a great measure neutralized, were it not for the manufacture of bleaching powder, which in its turn depends on those of sulphuric acid and of soda. I need not do more than allude to the use of the bleaching powder in paper-making, which is one great cause of the superior quality and low price of paper in Britain.

219. "Another important use to which the muriatic acid produced in the soda manufacture, and formerly thrown away, is now applied, is that of preparing cheap and superior *glue* from bones. Bones consist of bone-earth and glue; the former is readily dissolved by diluted muriatic acid,

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218. Explain the old process of bleaching, and state the advantages of the new plan.—**219.** To what important use is the muriatic acid, produced in the soda manufacture, now devoted?

while the latter is left, and has only to be dissolved in warm water to be ready for use. The acid solution of the bone-earth, on the other hand, promises to be an admirable form of using that earth as manure. Professor Liebig, in his late valuable work on Agricultural Chemistry, has recommended this application. At present, the solution in question is thrown away as useless in the glue manufactories.

220. *Refining of Silver.*—"The last application of sulphuric acid which I shall here mention is a very recent one, and owes its origin to one of the most scientific chemists of the day, M. Gay-Lussac. It consists of its employment in the refining or purification of silver. Silver, as it comes from the mines, is alloyed with one-half, or rather more, of copper. It also contains a small quantity of gold. It must be refined—that is, purified; and the pure or fine silver is then alloyed with the due amount of copper to form the standard silver.

221. "Raw silver was formerly refined by cupellation, a process which cost about 35*s.* for 50 lbs. of silver. The gold contained in the silver would not repay the expense of extracting it, and was therefore allowed to remain, and to circulate in the silver, absolutely worthless. But by means of sulphuric acid, cupellation is avoided; the silver is refined at a most trifling cost, and the gold is obtained by the same operation; nay, even the copper, which was formerly lost, is now preserved; and although the gold only amounts to from $\frac{1}{2000}$th to $\frac{1}{1200}$th of the weight of the silver, yet, as its value is about $1\frac{1}{2}$ per cent. of that of the silver, it not only repays the whole expense of refining, but leaves a clear profit to the refiners. This beautiful application of chemistry has given rise to the singular and apparently anomalous result, that the seller of raw silver receives from the mint the exact quantity of pure silver which his alloy, on being tested, is found to contain, and likewise the whole amount of the copper present in the alloy, thus apparently paying nothing for the process of refining. The refiner is paid by the gold which he retains, and which was formerly lost to every one. The saving effected by this improvement to the French mint is stated to have been enormous.

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220. What other important application of sulphuric acid has been discovered?—221. What are the advantages of refining silver by the new process?

222. "I must not dwell longer on details of this kind; but I would mention, in passing, that, but for the wonderfully low price of sulphuric acid, it would have been impossible to produce a number of useful articles not yet mentioned; such as the beautiful stearine candles, phosphorus, phosphorus matches, lucifer matches, and many other products remarkable for their superior quality, and for their astonishing cheapness. The present prices of sulphuric, nitric, and muriatic acids, of soda, soap, glass, phosphorus, &c. &c., would have been considered, a quarter of a century ago, as fabulous and impossible. Who can foresee what new discoveries, or what improvements on old ones, may arise during the next twenty-five years?"

223. *Application of Chemical Science in Medicine.*—The relations between chemical science and the resources of the healing art are obviously numerous; it will be sufficient to adduce one important instance on the present occasion. In 1812, M. de Courtois, a manufacturer of saltpetre at Paris, observed, in his process for procuring soda from the ashes of sea-weeds, that the metallic vessels were much corroded, and, in searching for the cause of the corrosion, he discovered one of the most singular and important of the chemical elements, *iodine.* Curiosity was excited; and the new substance, which might otherwise have escaped detection for ages, was traced to the sea-plants, from whose ashes the principal ingredient of soap is obtained, and ultimately to the sea-water itself. It was afterwards discovered in salt mines, and springs, and searched after in all bodies of marine origin—among the rest, in *sponge.* But the ashes of burnt sponge had been successfully employed as a remedy for one of the most unsightly and grievous disorders to which the human species is liable—the *goitre.* Nothing at that time was known of iodine; but the discovery of this substance in the ashes which had been empirically employed as a remedy, immediately suggested its use in this disease, and the result established the curious fact that iodine acts as a specific in goitre. "It is thus," says Sir J. Herschel, "that any accession to our knowledge of nature is sure, sooner or later, to make itself felt in some practical application, and that a benefit conferred on science by the casual observation

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222. What other advantages have resulted from the low price of sulphuric acid?—223. How was *iodine* discovered? How was its application in medicine established?

or shrewd remark of even an unscientific or illiterate person infallibly repays itself with interest, though often in a way that could never have been at first contemplated."

224. *Application of Chemical Science in the Arts.*—"The transformations of chemistry," observes the writer just quoted, "by which we are enabled to convert the most apparently useless materials into important objects in the arts, are opening up to us every day sources of wealth and convenience of which former ages had no idea, and which have been pure gifts of science to man. Every department of art has felt their influence, and new instances are continually starting forth of the unlimited resources which this wonderful science develops in the most sterile parts of nature. Who, for instance, would have conceived that linen rags were capable of producing *more than their own weight* of sugar, by the simple agency of one of the cheapest and most abundant acids—the sulphuric?—that dry bones could be a magazine of nutriment, capable of preservation for years, and ready to yield up their sustenance in the form best adapted to the support of life, on the application of that powerful agent, steam, which enters so largely into all our processes, or of an acid at once cheap and durable?—that sawdust itself is susceptible of conversion into a substance bearing no remote analogy to bread; and though certainly less palatable than that of flour, yet no way disagreeable, and both wholesome and digestible as well as highly nutritive? What economy, in all processes where chemical agents are employed, is introduced by the exact knowledge of the proportions in which natural elements unite, and their mutual powers of displacing each other! What perfection in all the arts where fire is employed, either in its more violent applications (as, for instance, in the smelting of metals by the introduction of well-adapted fluxes, whereby we obtain the whole produce of the ore in its purest state), or in its milder forms, as in sugar-refining (the whole modern practice of which depends on a curious and delicate remark of a late eminent scientific chemist on the nice adjustment of temperature at which the crystallization of syrup takes place); and a thousand other arts which it would be tedious to enumerate."—*Introd. to Nat. Phil.* p. 64.

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224. State some of the applications of chemical science in the arts.

GLOSSARY.

ACID. A substance which changes the blue, green, and purple juices of vegetables to a red colour, and unites with alkalies and metallic oxides to form salts.

ALEMBIC. An Arabic term for a chemical vessel of glass or metal, formerly used in distillation. See page 52.

ALKALI (*kali*, an old name for *potash*). A substance which changes blue vegetable colours to green, and unites with acids to form salts.

ALLOY. A compound of two or more metals, except when mercury is one of them, in which case the compound is termed an *amalgam*.

AMALGAM (*ama*, together, *gameo*, to marry). A compound of mercury with some other metal.

ANALYSIS (*ana*, again, *luo*, to solve). The separation of a compound into its elementary parts. See *Synthesis*.

ANHYDROUS (*a*, priv., *hydor*, water). Without water; as applied to crystals, gases, &c. See *Hydrates*.

ANNEALING. The process of heating a metallic body, and suffering it to cool again in a moderate temperature, in order to restore its malleability.

APHLOGISTIC LAMP (*a*, priv., *phlego*, to burn). A lamp which burns without flame (page 104).

ATMOSPHERE (*atmos*, vapour, *sphaira*, a sphere). The volume of air which surrounds the earth.

ATOM (*a*, priv., *temno*, to cut). That which cannot be divided; an ultimate particle of matter.

ATTRACTION (*attraho*, to draw to). The tendency which bodies have to be drawn to each other. It differs from *gravity* in being a more general term: gravity is a *species* of attraction.

AZOTE (*a*, priv., *zoe*, life). Life-depriver; a term applied to *nitrogen*, from its being incapable, alone, of supporting life.

BAROMETER (*baros*, weight, *metron*, a measure). A weather-glass; an instrument for measuring the varying pressure of the atmosphere.

BASIS (*basis*, a base). 1. The substance with which an acid is combined in a salt. 2. A *mordaunt*; a substance used in dyeing, which has an affinity both for the cloth and the colouring matter.

BI (*bis*, twice). A prefix signifying that the *base* is contained in a compound in two definite proportions.

CALCAREOUS (*calx*, lime). The name of a class of earths, consisting of lime and carbonic acid, as chalk, marble, &c.

CALCINATION (*calx*, lime). The process of forming a *calx*, or oxide, by exposure to intense heat in the open air.

CEMENTATION. A process by which the properties of a body are changed, on being surrounded by other bodies in a state of powder, and exposed to a high temperature, as in the conversion of iron into steel by cementation with charcoal.

CHALYBEATE (*Chalybes*, a people who dug iron out of the earth). The name of waters which contain iron.

CHEMICAL COMBINATION. The intimate union of two bodies, which forms a compound differing in one or more qualities from either of the constituent bodies.

COHESION (*cohæreo*, to cling together). The species of attraction by which the component parts of a body *cohere*, or are kept together. It is the antagonist of *expansion*.

CONCENTRATION. The strengthening of solutions, mixtures, &c., by evaporation of their watery parts.

CONDENSATION (*condenso*, to make thick). The act of diminishing the bulk of a body, as by the conversion of steam into water, gases into liquids, liquids into solids. When this is done by external force, it is termed *compression*.

CONGELATION (*gelu*, cold). The thickening, or solidification, wholly or in part, of a liquid. Thus water *congeals*, and becomes ice; the skins of animals, when dissolved in water by boiling, *congeal*, and become glue.

CREPITATION (*crepito*, to crackle). The crackling sound occasioned by certain salts during calcination.

CRUCIBLE (*crux*, a cross, which the alchemists stamped upon the vessel; or *crucio*, to torture). A chemical vessel in which the metals were *tortured*, to force them to become like gold.

CRYSTALLIZATION (*crystallos*, a crystal). The process by which the particles of liquid or gaseous bodies form themselves into *crystals*, or solid bodies of a regularly limited form.

CUPEL (*kuppel*, German, a cup). A small flat, *cup*-like crucible, made of bone ash.

CUPELLATION. The process of purifying gold and silver by melting them with lead, which is first oxidated, then vitrified, and sinks into the *cupel*, carrying along with it all the baser metals, and leaving the gold or silver upon its surface.

DECREPITATION (*de*, from, *crepito*, to crackle). The crackling noise which takes place when certain bodies, as salts, are heated.

DEFLAGRATION (*deflagro*, to burn). The oxidation of metals by mixing them with nitrate or chlorate of potash, and projecting the mixture into a red-hot crucible.

DELIQUESCENCE (*deliquesco*, to melt). The property of some salts of attracting moisture from the air, and becoming liquid.

DENSITY (*densus*, thick). A relative term, denoting the comparative quantity of matter in different bodies, which is contained in the same space.

DEOXIDATION. The process of depriving a substance of the *oxygen* which it contains.

DEPHLOGISTICATED (*de*, from, *phlogiston*, the inflammable principle). Deprived of phlogiston; oxidized. See *Phlogiston*.

DEUTOXIDE (*deuteros*, second). A term applied to a substance which is in the *second* degree of oxidation.

DIGESTION. The continued action of a solvent upon any substance.

DISTILLATION (*destillo*, to drop by little and little). The process of converting a liquid into vapour by means of heat, and of reconverting the vapour into liquid by means of cold. The subjection of bodies to a red heat in close vessels, and the collection of the products, constitute *destructive distillation*.

DUCTILITY (*duco*, to draw). A property of some metals, by which they may be drawn out into wire.

EFFERVESCENCE (*effervesco*, to grow hot). The commotion produced in fluids by the sudden escape of gas, as on pouring acid on chalk.

EFFLORESCENCE (*effloresco*, to blow as a flower). The pulverescence of crystals, as sulphate of soda, on exposure to the air. It is opposed to *deliquescence*.

ELASTICITY (*elauno*, to push back). The property or power by which a body, when compressed or extended, returns to its former state. See *Gas*.

EMPYREUMATIC (*empureuo*, to

set on fire). A term applied to the peculiar vapours produced by destructive distillation.

EQUIVALENT (*æquè*, equally, *valeo*, to avail). A term applied to the combining proportions of elementary and compound substances. It is frequently used in the same sense as the term *atom*.

EUDIOMETER (*eudia*, calm weather, *metron*, a measure.) An instrument for ascertaining the proportion of oxygen in a gaseous mixture.

EXPANSIBILITY (*expando*, to spread out). The property by which a body is capable of occupying more space than it usually requires; it is called into action by heat.

FLUX (*fluo*, to flow). A substance or mixture which is frequently added to assist the fusion of minerals.

FRIGORIFIC (*frigus*, cold, *facio*, to make). A term applied to certain chemical mixtures, which have the quality of producing extreme cold.

FULMINATION (*fulmino*, to thunder). The explosion which takes place in chemical bodies by friction or heat.

FUMING LIQUOR (*fumus*, smoke). A chemical mixture, which emits fumes or vapour, on exposure to the air

FURNACE. A fire-place employed for chemical operations. Furnaces have been termed *evaporatory*, when employed to reduce substances into vapour by heat; *reverberatory*, when so constructed as to prevent the flame from rising (p. 96); and *forge* or *blast* furnaces when the current of air is determined by bellows (p. 93).

FUSION (*fusus*, melted). The state of melting. Substances which admit of being fused are termed *fusible*, while those which resist the action of fire are termed *refractory*. Fusion differs from liquefaction in being applied chiefly to metals and other substances which melt at a high temperature. *Igneous fusion* is the melting of anhydrous salts by heat without their undergoing decomposition. *Aqueous fusion* is the solution of salts which contain water of crystallization, by heat.

GAS. An old Teutonic word, signifying air or spirit; it is now applied to any permanent aeriform fluid. *Gases* are distinguished from *liquids* by the name of *elastic fluids;* while liquids are termed *non-elastic*, from their having, comparatively, no elasticity. Gases are distinguished from *vapours*, by their retaining their elasticity in all temperatures. A *gaseous fluid* is distinguished from other fluids by its having the nature of gas.

GRANULATION. The pouring a *melted* metal into water, in order to divide it into small particles, or *granules*, for chemical purposes.

GRAVITY (*gravitas*, heaviness). The tendency which bodies have to fall to the centre of the earth. *Gravity* and *Attraction* are often used synonymously; the latter is, however, of more general application: we speak, for instance, of *capillary*, of *magnetic attraction*, but not of capillary, or magnetic gravity. For *Specific Gravity*, see p. 12.

HYDRACIDS. *Hydro-acids*. A class of acid compounds, into which hydrogen enters as the acidifying principle.

HYDRATES (*hydor*, water). Chemical compounds of solid bodies and water, still retaining the solid form. If water be not a constituent, the compound is said to be *anhydrous*.

HYGROMETER (*hygros*, moist, *metron*, a measure). An instrument for ascertaining the degree of moisture of the atmosphere.

HYGROMETRIC WATER. That portion of moisture which gases yield to deliquescent salts.

HYPER (*hyper*, over or above). This prefix is a Greek preposition, denoting *excess*, as in *hyper*-oxymuriatic acid, a compound containing *more* oxygen than oxymuriatic acid.

HYPO (*hypo*, under). This prefix is a Greek preposition, signifying *deficiency*, as in *hypo*-nitrous acid, a compound containing *less* oxygen than nitrous acid.

IGNITION (*ignis*, fire). An effect of caloric, implying the emission of light from bodies which are much heated, without their suffering any change of composition. Bodies begin to become *ignited*, or red-hot, at about 800° F.; the highest point of ignition is a *white light*.

INCINERATION (*incinero*, to reduce to ashes, from *cinis*, a cinder). The reducing to ashes by burning. The combustion of vegetable or animal substances, for the purpose of obtaining their ashes or fixed residues.

INFUSION (*infundo*, to pour on). The pouring of water, hot or cold, on vegetable substances, for the purpose of extracting their soluble and aromatic principles.

INTEGRAL PARTICLES (*integer*, entire). The most minute particles, *similar to each other*, into which a substance can be divided. Thus, the smallest portion of powdered marble is still marble; but if, by chemical means, the calcium, the carbon, and the oxygen, of this portion be separated, we then have the *elementary* or constituent particles.

LEVIGATION (*lævigo*, to polish). The process of rubbing earths and some metallic substances with a *muller* upon a flat table of hard stone. Some fluid is added to assist the operation, which in this respect differs from *trituration*.

LITHARGE (*lithos*, a stone, *arguros*, silver). An oxide of lead in an imperfect state of vitrification. Litharge is more or less white or red, according to the metals with which the contained silver is alloyed, the white being called *litharge of silver*, the red *litharge of gold*.

LIXIVIATION (*lixivium*, a ley). The solution of an alkali or of a salt in water, in order to obtain the soluble portion in the form of a *lixivium*, or ley.

LUTE. A paste made of clay, sand, and other materials, for closing the joinings of retorts, receivers, &c., for the purpose of rendering them air-tight.

MACERATION (*macero*, to make soft by steeping). The steeping of a body in a cold liquid, in order to soften it.

MAGISTERY (*magister*, a master). A *masterly* preparation; a term formerly applied to almost all precipitates.

MALLEABILITY (*malleus*, a hammer). A property of some metals, by which they may be beaten out into plates, or leaves, by the hammer.

MANIPULATION (*manipulus*, a handful). The mode of handling utensils in experimental philosophy.

MATRASS. A vessel of glass, earthenware, or metal, usually of a globular shape, and open at the top, for the purposes of digestion, evaporation, &c.

MATRIX. The earthy or stony matter which accompanies ores, or envelopes them in the earth.

MENSTRUUM. A term synonymous with *solvent*. A liquid which does not change the nature of the substance to be dissolved. The pretended universal solvent of the old chemists was called an *alkahest*.

METALLURGY (*metallon*, a metal, *ergon*, work). The separation of a metal from its ore. It comprises the several operations of assaying, refining, smelting, &c.

METEOROLITES (*meteoros*, floating in the air, *lithos*, a stone). Meteoric stones; aerolites; solid compounds of earthy and metallic

matters, descending from the at
sphere. They all contain iron
loyed with nickel.

MOLECULE (dim. of *moles*
mass). A minute particle of a r
or body. It differs from *atom*
being always considered as a
tion of some aggregate. See
tegrant Particles.

MUFFLE. A small earthen
fixed in a furnace, and used i
pellation, and other processes
require the access of air.

NEUTRALIZATION (*neute*
ther of the two). A term e
ing the effect, when an aci
an alkali are combined in su
portions that the compound d
change the colour of litmus
lets; in other words, the pro
of both are destroyed or *neut*

ORES. The mineral bodi
which metals are extracted
are termed *sulphurets,* wh
metals are combined with
oxides, when combined w
gen; *salts,* when combin
acids.

OXIDATION. The p
converting metals or ot
stances into *oxides,* by c
with them a certain qu
oxygen. It differs from
tion, in the addition of o
being sufficient to form a
the substance oxidized.

OXY- (*oxys,* acid). A
noting—1. the productio
sence of *acidity,* as in o
the presence of *oxygen,*
muriatic acid, the form
chlorine.

PELLI [illegible]
A [illegible]

parts of bodies, by *re-acting* upon their elements. It is synonymous with *test*.

RECEIVER. A vessel fitted to the neck of a retort, alembic, &c., for the purpose of *receiving* the products of distillation. It is also called *refrigeratory*, from its cooling the contents.

RECTIFICATION (*rectus*, right, *facio*, to make). The repeating a distillation or sublimation several times, in order to render a substance purer or finer.

REDUCTION (*reduco*, to bring back). A chemical process, also called *revivification*, by which a substance is *reduced*, or restored, to its natural state; the restoration of metallic oxides to the metallic state.

REFINING. The art of purifying any thing; particularly the assaying or purifying gold and silver, by separating them from other bodies which are combined with them.

REGULUS (*rex*, a king). The term *regulus* was originally applied by the alchemists to metallic matters when separated from other substances by fusion; it originated in their expectation of always finding gold, the *king* of metals, at the bottom of their crucibles, after fusion. The term was afterwards applied to the metal extracted from the ores of some of the metals, which formerly bore the name which is now given to those metals themselves; hence, regulus of antimony—of arsenic—of cobalt.

REPULSION (*repello*, to drive back). The property exhibited by the particles of bodies, under certain circumstances, of refusing to meet each other. It is the antagonist of *attraction*.

RETORT (*retortus*, bent backwards). A vessel employed for distillation, &c. See page 29.

ROASTING. A chemical process, by which mineral substances are separated, some of their principles being volatilized, and others changed, so as to prepare them for further operations.

SALIFIABLE BASE (*sal*, salt, *facio*, to make). A substance which forms definite compounds with an acid, and which, when liquid, or in a state of solution, has an alkaline reaction. The acid, of whatever kind it may be, was denominated by Lavoisier, the *salifying principle*.

SATURATION (*saturo*, to satisfy). 1. A fluid, which holds in solution as much of any substance as it can dissolve, is said to be *saturated* with it. 2. When two principles, which have united to form a new body, are in such proportions that neither predominates, they are said to be *saturated* with each other; if otherwise, the predominant principle is said to be *sub-saturated*, and the other *super-saturated*.

SESQUI (contracted from *semisque*, and a half). A prefix denoting the quantity and a half more.

SMELTING. The operation of fusing ores for the purpose of separating the metals from the substances with which they are mineralized.

SOLUTION (*solvo*, to dissolve). The state of being dissolved—the result of an affinity between bodies in different states with regard to cohesion. Liquids are called *solvents*, from their acting on, or holding in solution, either solids or aeriform fluids. The influence of heat upon the power of solution, corresponds with the difference between cohesion and elasticity; upon solid bodies, it generally *increases* the power of the solvent, by diminishing their cohesion; upon aeriform bodies, it *diminishes* the power, by adding to their elasticity.

SUBLIMATION (*sublimis*, raised on high). The process by which volatile substances are *raised* by heat, and condensed again into the solid form.

SUB-SALT. Originally, a salt which contained an excess of base. This term now relates to atomic composition, a true *sub-salt* being that in which there is less than one atom of acid to each atom of base; thus, the *sub*-carbonate of soda is no longer a sub-salt, but is generally termed carbonate of soda.

SYNTHESIS (*sun*, together, *thesis*, position). The formation of any body from its elements, as opposed to *analysis*, or the resolution of a body into its component parts.

TEMPERING. The operation of heating iron to a certain extent, which is indicated by the colour presented on the surface of the metal.

TENACITY (*teneo*, to hold). The degree of force with which the particles of a body cohere; a term particularly applied to metals which may be drawn into wire.

TEST (*testis*, a witness). A reagent; a substance which, being added to another substance, *tests* or distinguishes its chemical nature or composition.

THERMOMETER (*therme*, heat, *metron*, a measure). A measurer of heat; an instrument for comparing the degree of active heat existing in other bodies.

TRITURATION (*tritus*, from *tero*, to rub). The act of rubbing or pounding a substance.

VACUUM (*vacuus*, empty). An empty space. The term is used to denote the interior of a close vessel, from which the atmospheric air and every other gas have been extracted. The *vacuum* produced by means of an air-pump is always imperfect; the vessel is, nevertheless, termed an *exhausted receiver*.

VAPORIZATION (*vapour*, vapour). The conversion of a liquid into vapour. It may be considered under the heads of *ebullition* and *evaporation*. A *vapour* differs from a *gas* in its want of permanency, for it returns to the liquid state, when exposed to a diminished temperature.

VITRIFICATION (*vitrum*, glass, *facio*, to make). The conversion of a substance, as silica, into *glass*.

VITRIOL (*vitrum*, glass). A term originally denoting *any* crystalline body possessing a certain degree of transparency. There are at present three substances so designated —the *green*, or sulphate of iron; the *blue*, or sulphate of copper; and the *white*, or sulphate of zinc.

VOLATILITY (*volo*, to fly). A property of bodies, by which they are disposed to assume the state of vapour, and *fly off*.

VOLUME. The *apparent* space which a body occupies is called its *volume;* the *effective* space which the same body occupies, or its real bulk of matter, is its *mass;* the relation of the mass to the volume, or the quotient of one by the other, is its *density;* and the empty spaces which render the volume larger than the mass, are its *pores*.

WELDING. A property of certain metals, by which, at a white heat, an incipient fusion takes place, which covers their surface with a kind of varnish, so that, when brought into contact in this state, different metals may be permanently united by forging.

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